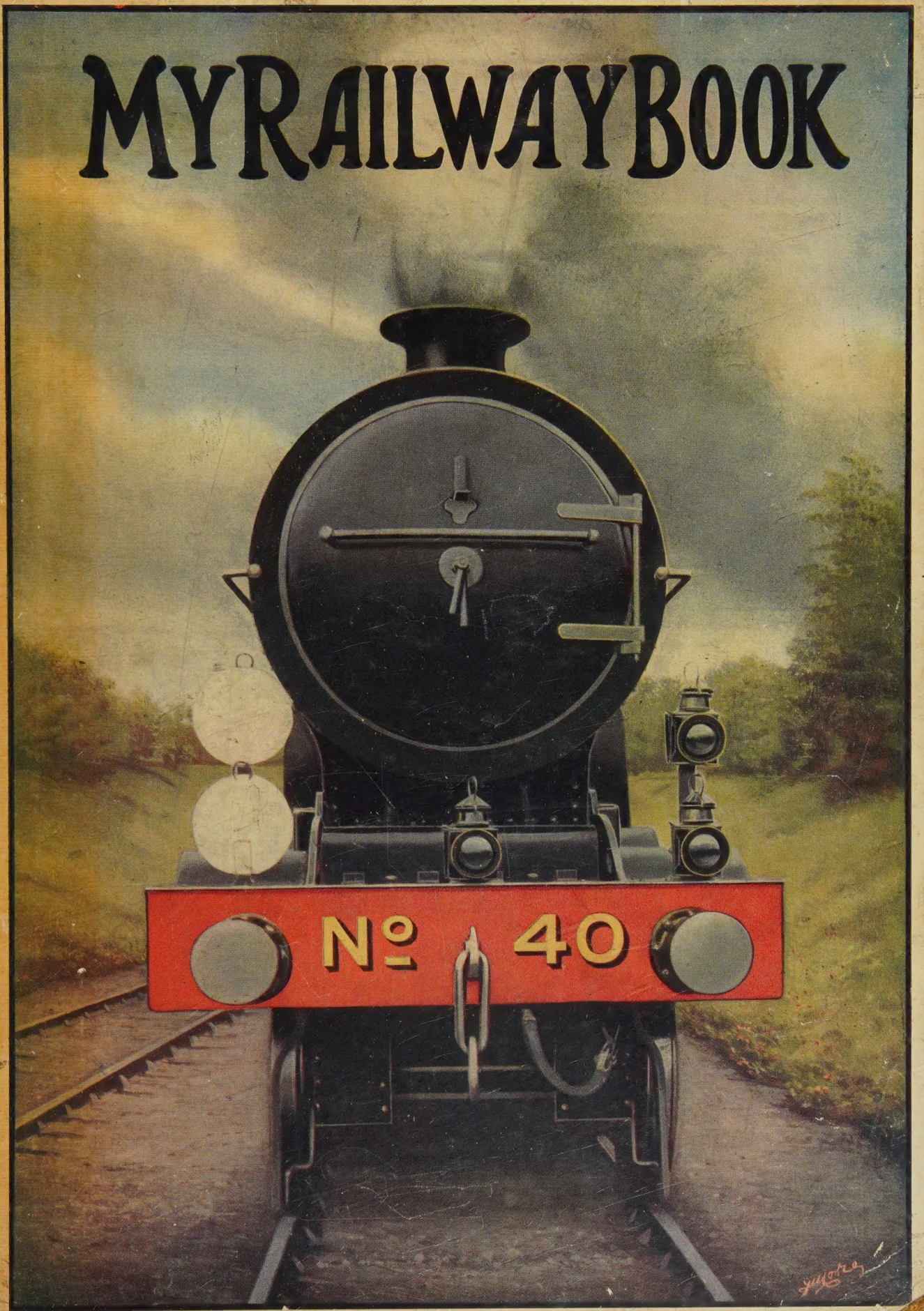
MY RAILWAY BOOK



With Best Wishes
for your birthday.
March 22. 1926.
Jo Armorel.
From. Henry.

X72

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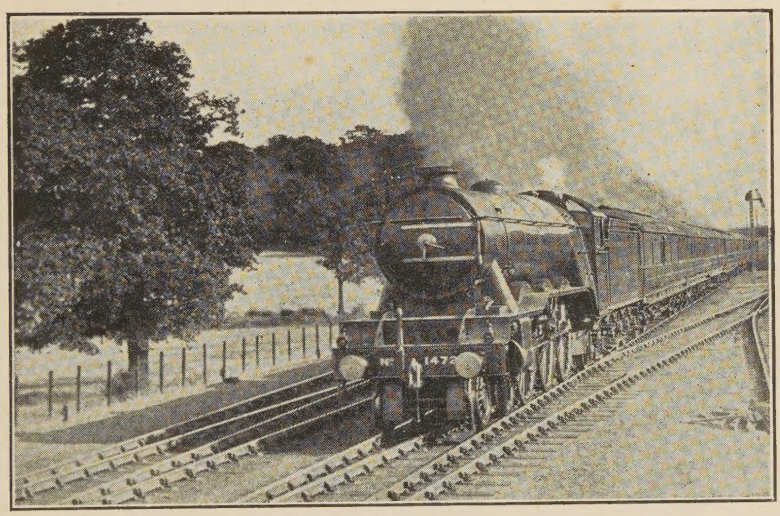
A Heavy Express Train Leaving King's Cross, L.N.E.R.

MY RAILWAY BOOK

THE WONDERFUL RAILWAY ENGINEERING PROGRESS OF ONE HUNDRED YEARS, ILLUSTRATED AND DESCRIBED FOR CHILDREN

BY

CECIL J. ALLEN, A.M.Inst.T.



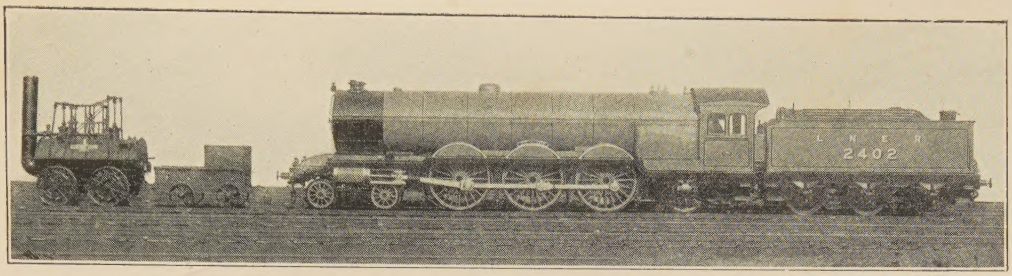
The "Flying Scotsman"

LONDON
JOHN F. SHAW & CO., LTD.
3 PILGRIM STREET, E.C.4

PART I

CONTENTS

	PAGE
One Hundred Years of Railway Travel	1
Picking up Water at Full Speed	6
Showing Passengers How to Find Their Trains	9
Meals on Wheels	10
A Curious Locomotive	15
Fighting the Snow	17
Slipping Coaches	21
Riding with the Engine-Driver	25
Some Modern Wonders of Travel	31
Crossing a Continent—The Story of the Canadian Pacific Railway	33
Railway Coaches—Past and Present	39
Railways in Miniature	49
Engine Headlights and Discs	56
Sleeping While You Travel	62
Railway Bridges that Open	65
World-Famous Express Trains	68
Tunnels	76
Locomotives and Their Work	81



1825–1925: A Striking London and North Eastern Railway Comparison

ONE HUNDRED YEARS OF RAILWAY TRAVEL

IT is exactly one hundred years ago that the first railway was opened to carry passengers. It ran between the towns of Stockton and Darlington, away up in the county of Durham. On the left-hand of the picture above you see the very first engine that ever worked a passenger train, not only in this country, but in the world.

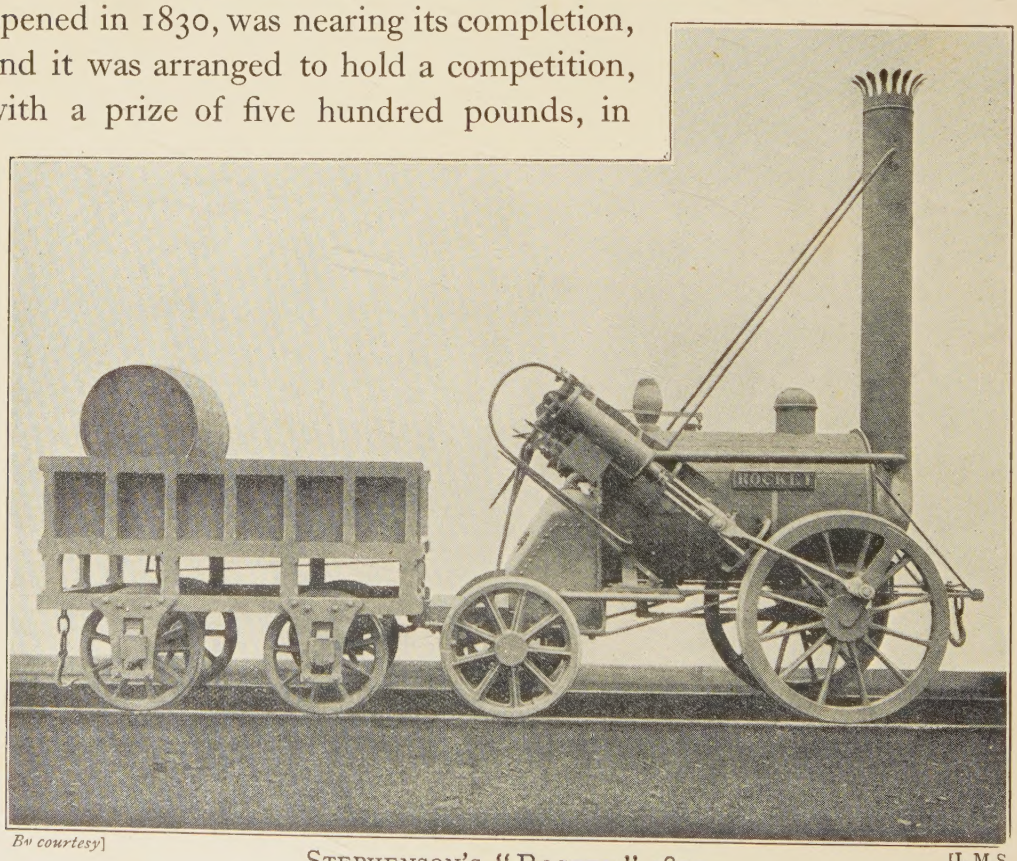
For many years this little engine, " Locomotion "—No. 1 of the Stockton and Darlington Railway—has been preserved on a pedestal at Darlington Station ; and in 1924 it was put once again on the rails and bravely made the journey of two-hundred-odd miles from Darlington to the great British Empire Exhibition at Wembley. There, no doubt, many of you saw it—standing alongside one of the latest and most powerful London and North Eastern locomotives, " The Flying Scotsman."

You have a similar contrast in the photograph at the head of this chapter, which shows another modern London and North Eastern " Pacific " engine, actually built at Darlington, end-to-end with little " Locomotion." Nothing could bring home to us in a more remarkable way the development of a hundred years in railway travel, than the difference between the 11-ton engine of 1825 and the 150-ton locomotive of 1925. " Locomotion " could travel at from

six to eight miles an hour, whereas the great " City of York " is good for seventy-five miles an hour and more.

" Locomotion " was not, however, the first steam engine. Murdoch, in 1784, designed a steam locomotive to run on the high roads. One dark night, when he was trying his invention along a secluded lane near Redruth, in Cornwall, where he was working, he so frightened the worthy vicar of the parish—whom he met on the way—that the vicar thought he must be face-to-face with the Evil One himself !

Then, in the year 1803, a man named Trevethick designed and built, in South Wales, the first locomotive engine to run on rails. But perhaps the most famous of the early engines was Stephenson's " Rocket." The Liverpool and Manchester Railway, which was opened in 1830, was nearing its completion, and it was arranged to hold a competition, with a prize of five hundred pounds, in



By courtesy] STEPHENSON'S " ROCKET," 1829 [L.M.S.

PAST AND PRESENT ON THE CANADIAN PACIFIC RAILWAY

order to decide what would be the best type of engine to use on the railway.

It was the " Rocket " that proved the victor. To the credit of this far-seeing engineer be it said that some of the features of design that he included in his engine of long ago are still standard in our engines of nearly a hundred years later. All the tests were complied with, and the " Rocket " attained a speed of twenty-nine miles an hour—a much higher speed than had ever previously been run.

The vast importance of railways, which in their earliest days had been bitterly opposed, very soon began to be realised on all hands. New railways were planned in all directions. By the year 1838 the mails had been transferred from the mail-coaches to the trains. Eight years later people had become so tremendously in favour of travel by railway that, in the year 1846, no less than 272 different "Acts " were passed by the Houses of Parliament to sanction the building of railways in different parts of this country.

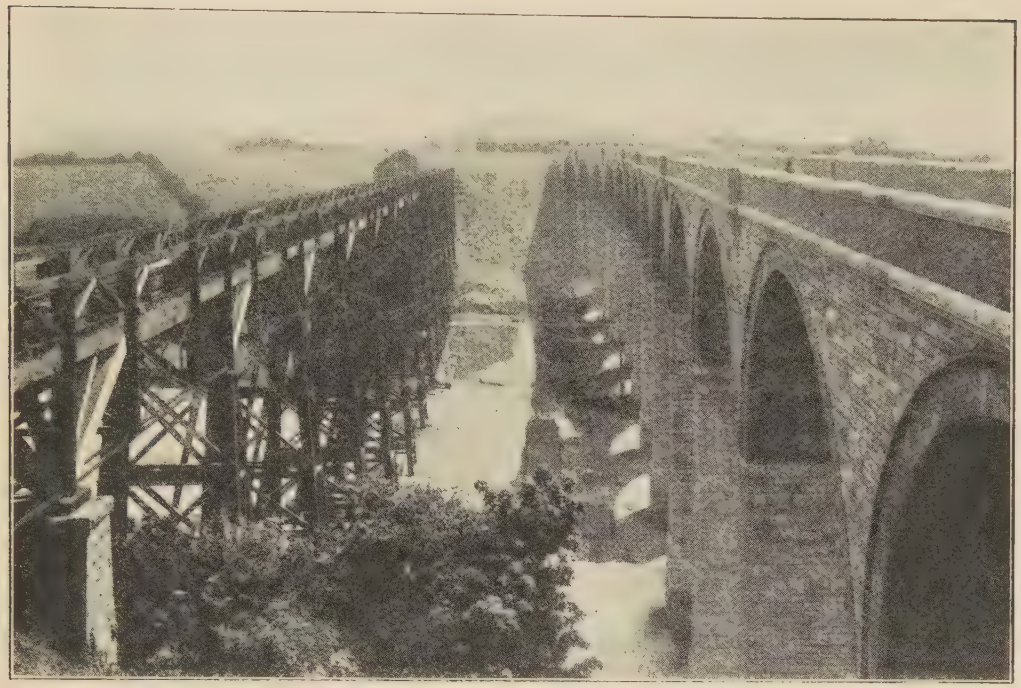
One by one the bigger railways have swallowed up the smaller ; and in the year 1923 there came into force what is known as the

" grouping " of the railways. By this Act of Parliament all the many railways of Great Britain, except just the London Underground railways, have been swallowed up into four vast groups. Up the western side of England and Scotland there lies the network of the biggest group—the London, Midland and Scottish—and up the eastern side that of the London and North Eastern Railway ; the Great Western Railway stretches its wide-spreading arms all over the West Country, and the Southern Railway occupies the south.

The hundred years of railway development has produced no less than 24,400 miles of railway in the British Isles. If these railways were stretched out end-to-end they would all but girdle the world. To-day it would be impossible to do without them. Just as the veins and arteries in the human body carry the blood which is the basis of life, so the railways are to the country like the veins and arteries which carry the raw materials and the finished products of the industries that are the basis of our national life.

Much of the traffic which used to go by railway now goes by road,

Photo] A Present-day Pullman Car Express on the L.N.E.R. [F.E. Mackay



How Stone Viaducts have replaced Timber Trestle Bridges on the Great Western Railway

and more will so travel in the future, especially over the short distances, where the roads offer "door-to-door" travel with which the railways cannot compete. The air, too, will by degrees become more safe and less costly. But nothing can ever replace the wonderful carrying capacity of the railway. Just try and think how many road lorries would be needed to carry the thousand tons of merchandise or minerals of a present-day goods train ! Or how many motor-buses or cars or aeroplanes would you require to convey the five hundred passengers of an express, or the eight hundred or even a thousand passengers of a suburban train ?

It is not my intention in this book to tell you very much about the past, as there are more than enough wonders in our railways of to-day to occupy our attention in its pages. But we need to pause for a moment and think how amazing has been the development of the railway—practically unknown a century ago, and now spread over the wide world to a total length of three-quarters of a million miles.

Photo] [F. E. Mackay

TAKING WATER FROM IPSWICH WATER-TROUGHS, L.N.E.R.

PICKING UP WATER AT FULL SPEED

LOCOMOTIVE engines are terribly thirsty monsters. On such a run as that of the wonderful Great Western "Cornish Riviera" express—which flies every day over the two hundred and twenty-six miles from Paddington terminus in London to Plymouth without stopping anywhere on the way—the engine will swallow quite easily over thirty tons of water.

Now, how is so tremendous a quantity as this to be stowed away ready for use? It would need three or four ordinary engine tenders to hold as much, for the big water-tank in the tender of a Great Western express engine can only find room for about three thousand five hundred gallons all told.

Many years ago, a well-known locomotive engineer named Ramsbottom foresaw that in days to come we should want to travel long distances without stopping, and that this question of water would

be a difficulty. So he thought out a clever arrangement by which an engine could scoop up fresh supplies while running at full speed.

What he did was to find a perfectly level stretch of line, and there to lay down between the rails a shallow trough, rather over a quarter of a mile long, filling it with water. Probably all of you have seen, at some time or other, those long shining ribbons of water in the centre of the railway track ; the nearest to London, for example, may be found at Bushey, near Watford, on the North Western main line, and at Ruislip, on the Great Western main line to Birmingham.

As the express nears the beginning of the trough, the fireman lowers, by suitable machinery, a hinged scoop under the tender, in the shape of a bucket. By a very slight downhill gradient in the track the scoop is then lowered into the trough, and the speed at which the train is travelling forces the water, at very great pressure, up out of the trough through a big vertical pipe into the tender tank.

Most water is not picked up at the highest speeds, as you might think ; when the train is travelling very fast, as in this picture of a

Photo\ [F. E. Mackay

BIRMINGHAM EXPRESS TAKING WATER AT 80 MILES AN HOUR, G.W.R.

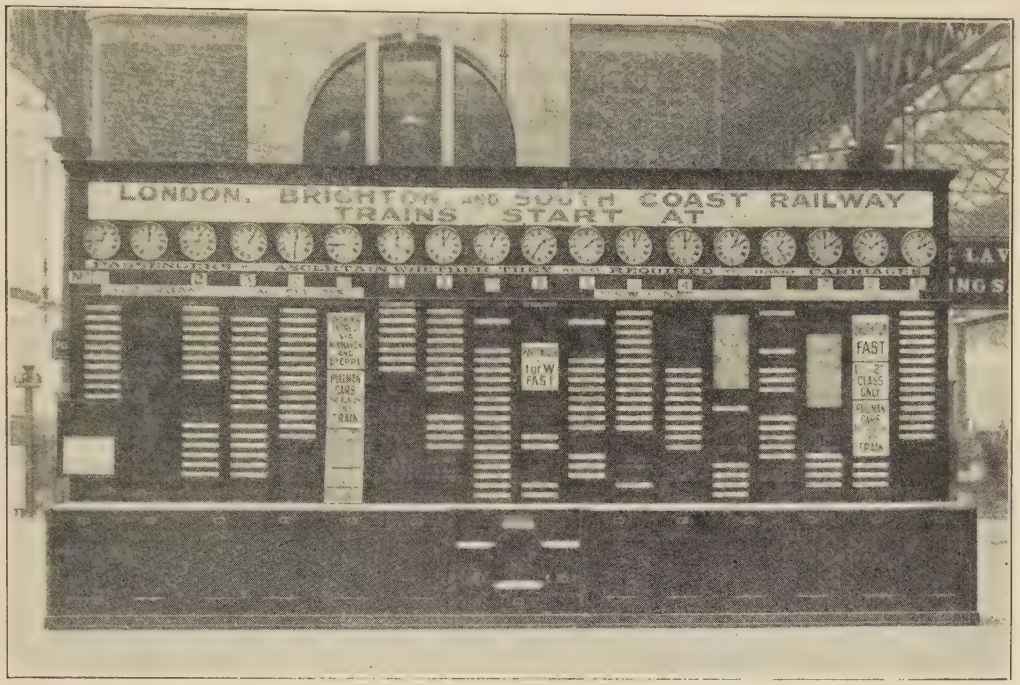
Great Western Birmingham two-hour express—which was probably doing round about eighty miles an hour—a lot of water is scattered at the point of the scoop, and makes the big " splash " that you see.

As soon as the tender tank is full, which the fireman can see by means of a gauge on the footplate, he lifts the scoop out of the water ; in the space of ten or fifteen seconds anything from a thousand to fifteen hundred gallons may have been picked up. On the journey to Plymouth, to which I have referred, it is possible to pick up water four times ; if you are travelling by the West Coast route to Scotland, there are no less than nine sets of troughs between Euston and Carlisle.

The advantage of the troughs is not only that of saving the weight of enormous tenders or saving time in stopping to take water. Locomotives are very particular about what they drink. What is called " hard " water causes deposits to form all over the parts of the boiler where steam is being produced, and makes an engine steam badly. But the laying down of water-troughs just where the water is of best quality, as well as cheap and plentiful, enables the engines to take as much as they need, without having to stop for the purpose.

Photo] [F. E. Mackay

PICKING UP WATER ON THE L.M.S., NEAR MANCHESTER



A Remarkable Train Indicator at Victoria Station, Southern Railway

SHOWING PASSENGERS HOW TO FIND THEIR TRAINS

AT some of our big terminal stations, in days gone by, it used to be a regular puzzle to find out where your train was going to start. Not infrequently it involved a frenzied hunt all over the station before the missing train was "discovered." But nowadays such troubles are past.

Here is a picture of a remarkable indicator at Victoria Station of the Southern Railway. It is planned to show no less than eighteen trains at a time. First of all, if you look at one "column" at a time, you see a little clock at the top, which is set to show the time at which the train is going to start. Then, under that, you find the number of the platform at which you must look for it. And then, below that again, you see exactly at which stations the train is going to stop on its journey.

There is room in each column to indicate twenty different stations. The names of the stations are fixed on rollers, each roller having eight faces ; the rollers are turned by a row of handles at the side, which can be got at by opening a hinged cover at the side of each column. The actual names put on each roller have to be thought out very carefully, so that each column of the indicator may be able to show a number of different routes.

Any extra notices, like those about the Continental trains or the Pullman cars, are printed on loose enamelled plates, and hung on the indicator just where required. The men who work these indicators grow by degrees into walking time-tables themselves, and it is little short of marvellous to see how throughout the long working day they indicate all the different trains, seldom making a mistake and nearly always doing their work entirely from memory.

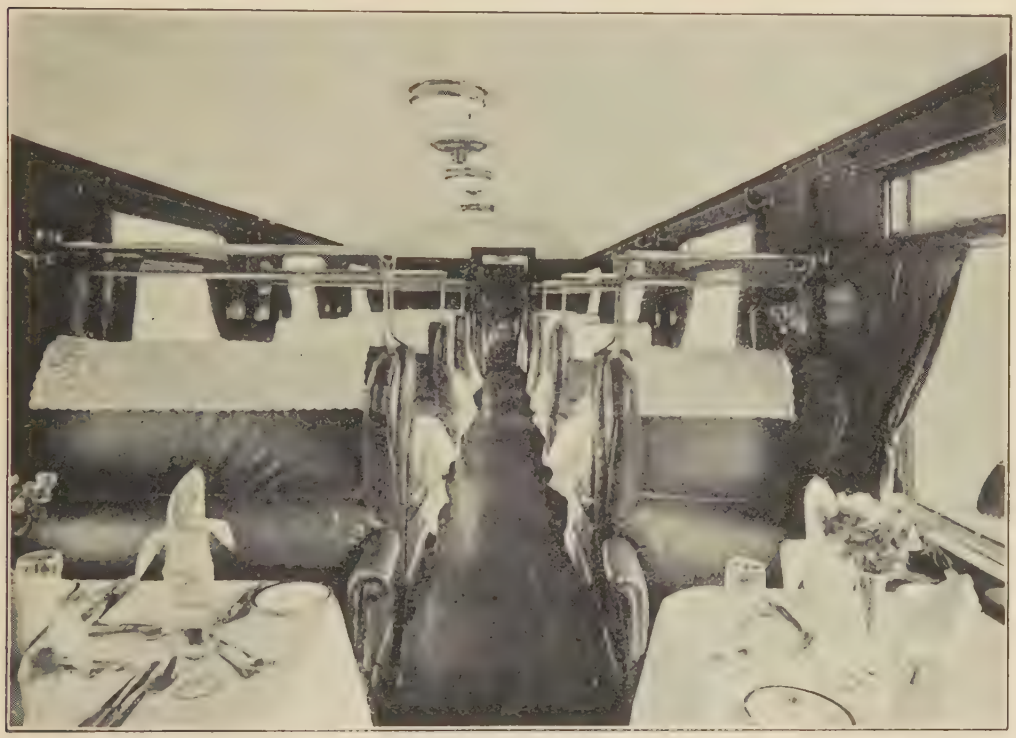
MEALS ON WHEELS

HOW very different travelling would be to-day without our dining cars ! Many of you very likely see the inside of a dining car only when you are going on long holiday journeys, and so perhaps you look upon it as rather a rarity. But you would be astonished to hear that in the summer-time, when the number of people on holidays bent makes it necessary to run more long-distance express trains than at any other time in the year, nearly seven hundred trains run in this country every day with restaurant cars attached to them. So you need never go hungry on the railway !

Not all the restaurant cars are the big coaches shown in these pictures. Sometimes, on trains which travel in the afternoons, when only teas and light refreshments are needed, there is provided a " buffet " car. An ordinary corridor coach is taken, and in one or two of its compartments, instead of seats for passengers, there are fitted up a tiny kitchen and pantry, with arrangements for boiling

water to make tea, and for washing up, as well as storage space for crockery and eatables. The " teas " are then prepared on trays, and the attendants carry them to passengers in the train, just where they sit.

But such an arrangement would never do where there are meals to be served, and cooking has to be done. Cooking on a large scale requires a great deal more room, and very careful planning and



First-Class Dining Car on the "Flying Scotsman," L.N.E.R.

equipment of the kitchen, or the work could never be got through in the limited time available. Indeed, some of the latest dining car " sets " on the London and North Eastern and London, Midland and Scottish Railways have separate " kitchen cars "—coaches given up entirely to kitchen, pantry and accommodation for the restaurant car staff.

At busy times the work in the restaurant car is really hard. Some-

New Kitchen Car, London, Midland and Scottish Railway

times, and more especially at lunch, seventy or eighty people will sit down at once, and when you think that each one is going to be served with soup, then fish, then joint, then sweets and then cheese, you will get some idea of the number of knives, forks, spoons, plates and glasses to be washed up, let alone the serving of the food ! Remember all the time the limited size of the kitchen and pantry, as you can see in these pictures, and you will understand the difficulties.

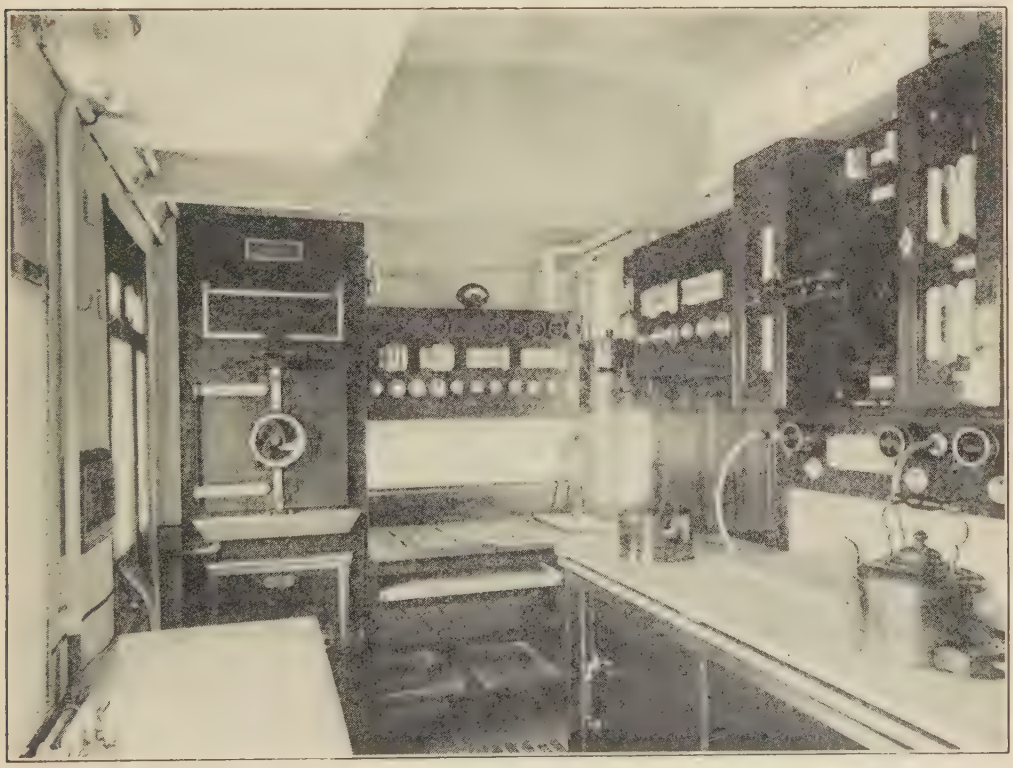
And then it is not as though one meal only were served. On long-distance trains like the East and West Coast Scotch expresses, or the Cornish trains of the Great Western Railway, there will generally be three " sittings " to accommodate all the people who want to take lunch, and sometimes even four, one after another. All the work of serving each " relay " of people, of collecting the bills, and then of washing up and laying the tables again, has often to be got through in less than an hour. On other trains, again, as soon as lunch is disposed of, the service of teas must begin ; and teas, again, have to give place to dinner, for all of which much preparation is necessary.

When the train is starting from a terminal station shortly before

a meal is going to be served, it is frequently the practice to put the joints on board already cooked, or partly cooked, from a kitchen on the station premises. Pastry, too, and soup is usually handed on to the trains ready-made. But on other trains every scrap of cooking is actually done on the train itself.

In the very first dining car on record, which ran on the Great Northern Railway between London and Leeds in 1879, the cooking was carried out in the oven of an ordinary kitchen range ; this was long before the days of electricity or gas on the trains. The people who wanted to dine had to take their seats in the car, for there were no corridors, either ; and the catering was done by a gentleman who owned a restaurant in Leeds.

To-day it is chiefly gas that is used for cooking purposes. But



Electric Kitchen on the L.N.E.R. "Flying Scotsman"

on the very latest restaurant cars of the London and North Eastern Railway, the cooking is carried on by electricity. You can see, in the picture of the inside of the kitchen on the new " Flying Scotsman," how the *chef* has electrical cooking appliances all round him. He appreciates the electric cooking immensely ; it is so much cooler in the kitchen than with gas, and it is better for the food, too.

The electricity for cooking, just like that which lights the compartments, is made by the train itself while running. Underneath the coaches you may see the dynamos generating electricity ; they are driven by belts off the axles of the wheels. Electricity is stored for use in large accumulators, also carried under the coaches, like the accumulators you use for your wireless set, only on a much larger scale.

An Indian Dining Car, Great Indian Peninsula Railway

INDIAN RESTAURANT CAR

In this country the dining cars usually travel through with the train from the beginning to the end of its journey, and passengers who want to take meals are allowed, if they desire, to sit all the time in the cars instead of in an ordinary compartment. But on the Continent, or in America, where the journeys are of tremendous length, day and night continuously, the cars are often attached to the train just at breakfast-time, or lunch-time, or dinner-time, for the meal to be served, and then taken off again. This saves hauling a heavy restaurant car along during the night-time, when it is not needed.

So the restaurant car business has grown to an enormous extent in the brief space of forty-five years. In fact, with the working also of refreshment rooms and hotels, the business of catering is one of the most important of railway activities to-day.

A CURIOUS LOCOMOTIVE

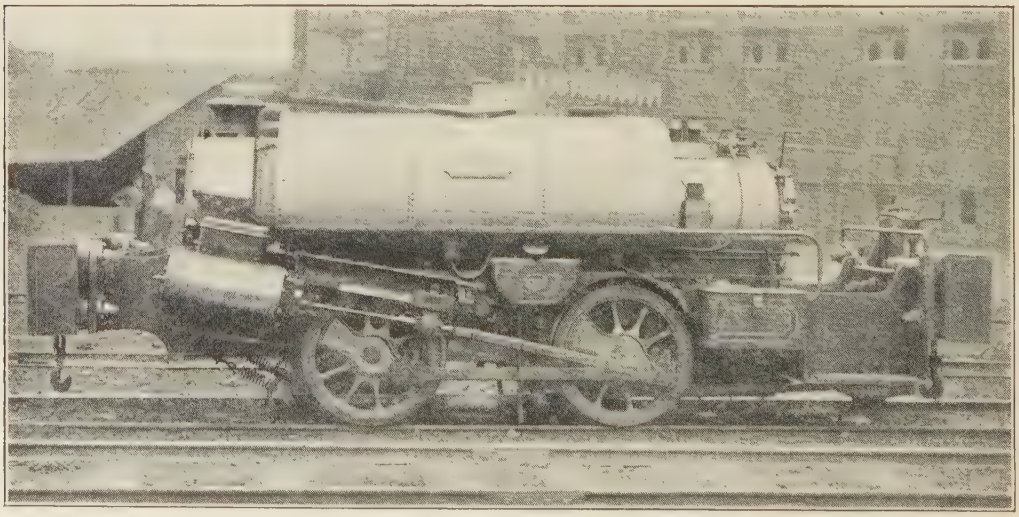
THE engine illustrated on the next page is not only a strange-looking creature, but it runs on a little-known railway. At a place called Beckton, on the east side of London, is found the vast works of the Gas Light and Coke Company, which makes gas for nearly all that part of the great Metropolis north of the River Thames.

Although the works only covers some 270 acres of ground, yet

into this small area there are crowded over forty miles of railway. Gas is made by " baking " coal in what are called " retorts," and what is left of the coal is known as coke. The coal for the gas-making, which arrives both by water, up the Thames, and also by rail, has to be taken into the various " retort-houses," and then the coke is withdrawn from the retorts, when the operation is complete, and taken away by rail or sea wherever required.

It was specially in order that this engine might be able to go through the doorways into the retort-houses that it was designed in so curious a fashion. Instead of the thirteen feet or so in height available on an ordinary railway, it had to be cut down in height to only 6 feet 6 inches, and it has, with its sisters, earned the nickname of " Jumbo." Even the engines in use elsewhere at Beckton, though not quite so diminutive, are kept down to 8 feet 6 inches in height, as they all have to work through confined spaces in various parts of the works

The water supplies are carried in a " saddle tank " on the top of the boiler. Although apparently so small, these engines are quite capable of hauling a load of over two hundred tons behind them.



A " Jumbo " Engine on the Gas Light and Coke Company's Railway

EXCURSION TRAINS TO BLACKPOOL TAKING WATER FROM KIRKHAM TRACK-TROUGHS.

CLEARING A SNOWDRIFT ON THE BERNINA RAILWAY, SWITZERLAND

FIGHTING THE SNOW

(All photos by courtesy of the Swiss Federal Railways)

SNOW, which we so love to see in the winter-time, is looked on with very different feelings by the railways. In the South of England, of course, we do not often have falls heavy enough to block the railways, but up in the Highlands of Scotland, or out in a country like Switzerland, handling the snow is a costly business, every winter alike. Special snow-ploughs have to be maintained in order to keep the lines clear, and the snow is sometimes too much even for them. As you will see by the picture above, the snow-plough on the Bernina Railway is having its work cut out to get through a heavy drift.

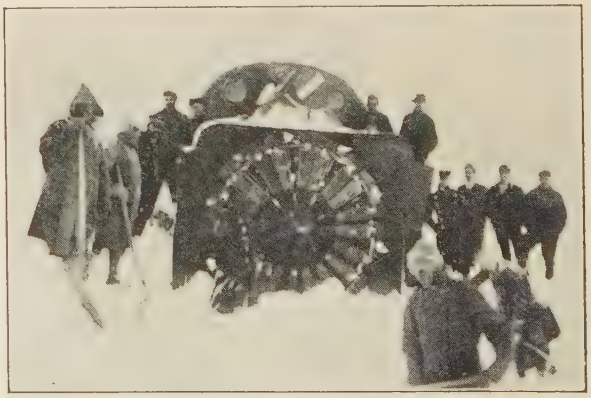
This type of snow-plough, which is shown in better detail at the bottom of the next page, is a comparatively recent invention. The

CLEARING THE SNOW—THE OLD WAY

older method, as shown here, was to clear the line of snow, after a drift, by means of hand labour—a most lengthy and laborious job, as you can well imagine. Then a snow-plough was invented, in shape rather like the ram of a battleship, and with two or three locomotives behind it, the plough "charged" the drifts, and shouldered them off to both sides of the line.

But where really deep drifts are encountered, this last type of plough is unable to cope with them, and in countries like Switzerland, or where the Rocky Mountains of America are crossed, ploughs of the "rotary" type are always now used. The Bernina snow-plough at the bottom of this page is a rotary plough. The big vanes are made to revolve very rapidly by steam power, and so, cutting into the drift as the plough slowly advances, they throw the snow off to one side in a tremendous cloud, as you can see in the photograph at the bottom of the opposite page, as well as the picture at the head of the chapter.

Apart from the use of ploughs when the line is blocked, however, special measures are taken on railways which are subject to heavy snowfalls, to keep as much snow off the line as



CLEARING THE SNOW—THE NEW WAY

A Deep Drift on the Loetschberg Railway

possible. In exposed parts of Scotland, you will see "snow fences" put up, at the side of the line, to keep the snow from drifting on to the metals when the wind is high; it is this "drifting," of course, which gives the most trouble, rather than the actual depth of snowfall—that is, the way in which the snow piles itself up after falling, in cuttings in particular.

In mountainous countries like Switzerland there are worse dangers. Sometimes, high up on the mountain-side, a mass of snow breaks loose, and begins to slide downwards. Gathering both force and speed in its descent, the dreaded avalanche sweeps away everything in its path, and not only snow and ice, but often soil, rocks and trees come down into the valleys in one huge mass. If a railway should be met with on the way, it would fare very badly.

So, where the railways are carried along the mountain-sides, as is so often the case, at points where avalanches are known to have come down in the past, or where, indeed, they are of frequent occurrence, the rail-

Another Snowdrift on the Loetschberg Line

STONE GALLERIES OR TUNNELS

STONE AND TIMBER GALLERY

SPECIAL PROTECTION AGAINST AVALANCHES, LOETSCHBERG RAILWAY

Connaught Tunnel, in the Selkirk Mountains.
Canadian Pacific Railway.

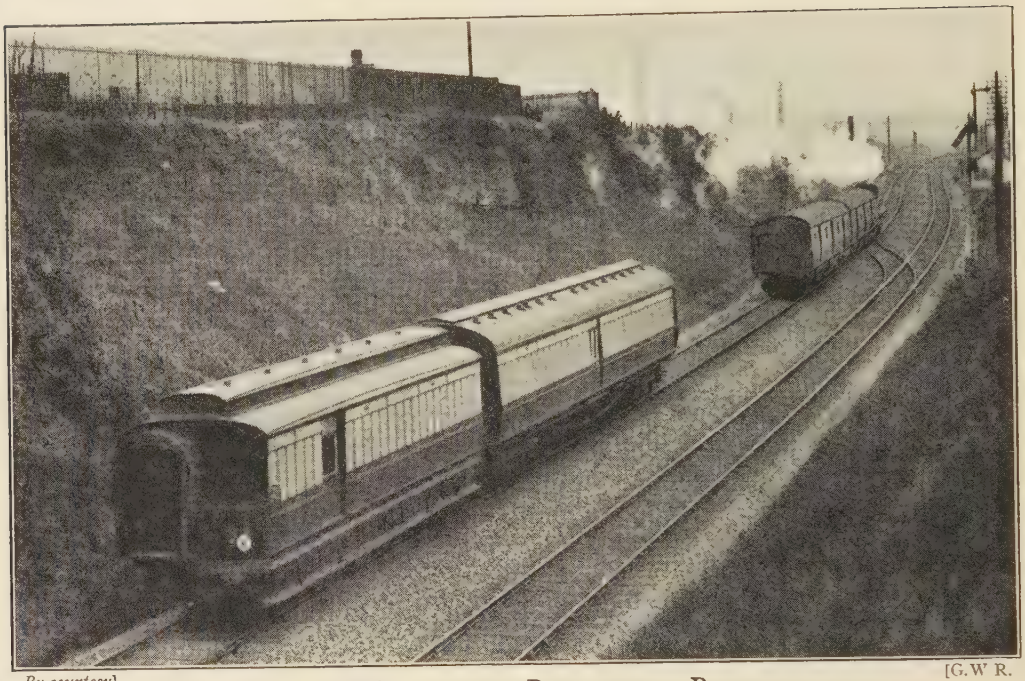
way is carried under artificial tunnels, specially constructed to throw the avalanches clear over the line. You can see these galleries very clearly in the photographs of the Loetschberg Railway opposite. This line runs through a wild and inhospitable mountain region, often high up on the sides of deep valleys, where snow reigns supreme in the winter-time. In fact, one of the camps established for the men making the line, at a place called Goppenstein, was actually swept away by an avalanche, and a number of men were killed. So the engineers of the railway were taught to respect the power of King Snow, and to make proper preparations to fight him.

SLIPPING COACHES

IF you look in the Great Western time-table at the times of the "Cornish Riviera Express," you will notice that, although the famous "flier" makes no stop all the way from London to Plymouth, yet you may get into it and travel to certain stations which are passed long before Plymouth is reached. Westbury is one such station; Taunton is another; and Exeter is another. How is this done? It is clear that the railway company does not intend you to jump out of the window!

Look again at the time-table, and you will see in the "Cornish Riviera" column, against each of those stations, the mysterious word "Slip." Briefly, this means that at Westbury, and at Taunton, and at Exeter, coaches are dropped off the back of the train, carrying passengers to these stations without stopping to set them down.

Suppose that you visit Paddington terminus one morning just before half-past ten, in order to see how this operation of "slipping coaches" is to be performed. Walking backwards from the engine, you will note first of all the through coaches for Penzance, St. Ives, Falmouth and perhaps one for Plymouth, and then the continuous passage, or "gangway," connecting the coaches, comes to an end.



By courtesy] [G.W.R.

SLIPPING COACHES AT BEDMINSTER, BRISTOL
Notice the special slip tail-lights.

The next coach is one of the two forming the " Exeter slip." If you look very carefully at the front of it, you will see various unusual fittings. There is, for example, a motor horn. The connection between the two halves of the rubber hose-pipe which you always find between the coaches of a passenger train (and which provides the means whereby the engine-driver is able, from the engine, to apply the brakes on every carriage right down his train) is much more complicated than usual.

And then, very particularly, you will notice that the hook on the slip-coach, which holds the coupling of the coach in front, has a hinge in it. If this hinge were to swing outwards, the coupling would be released, and the train would break in half ; but it is held tightly in position by means of a sliding steel bar, or wedge, on top. The front compartment in the slip-coach is for the slip guard, who will be responsible for severing the train at the right place ; and in

this compartment you will see the lever by means of which the sliding bar, to which I have just referred, is withdrawn.

To cut a long story short, if you were allowed, as a special privilege, to travel with the Westbury slip guard, as the express neared Westbury you would see him begin his preparations. Within about a quarter of a mile of that station he would pull his slip lever right over ; the hook would swing round on its hinge and let go the coupling ; and the slip would be " off." Automatically the brake hose-pipe on the back of the express itself stops itself up, " sealing the vacuum," as it is termed ; otherwise the express would be brought to a sudden halt.

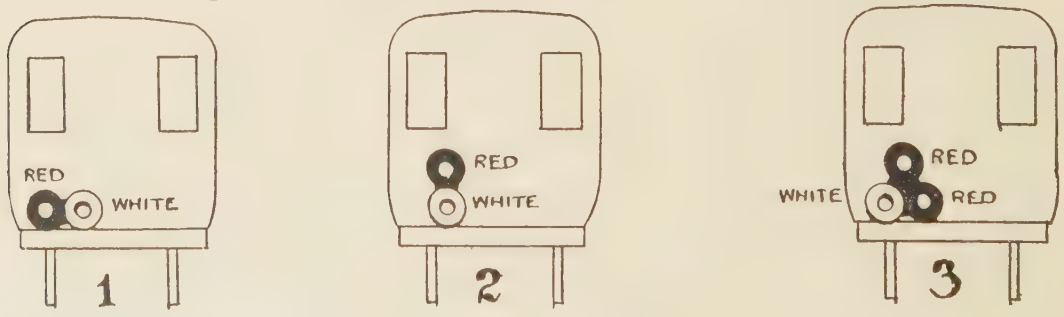
In pulling his lever over, the slip guard also applies the brakes slightly on the slip portion, so that the latter quickly draws away from the express. Then he signals out of his side-window to the driver

SLIPPING COACHES AT BROXBOURNE, L. & N.E.R.
The slip guard is just waving his green flag to the driver.

with a green flag, to show that he has " slipped " successfully, and the last thing remaining is carefully to bring the slip to rest at the station platform by the use of his brakes. The motor-horn in front of the slip-coach, which is worked with a foot-bellows, is to warn people that the slip-coach is coming ; this is very necessary, as men employed on the station or on the track are apt, unthinkingly, to get on to the line after the express has passed, forgetting that the slip is coming along behind.

The Great Western Railway does a great deal in the way of slipping coaches ; there are, in fact, some thirty-eight slips daily at various points on the system. Few other railways, however, adopt the practice ; there are one or two slips on the Brighton and South Eastern sections of the Southern Railway, and on the late Great Eastern and Lancashire and Yorkshire lines and in Ireland, but none elsewhere, or, for that matter, in any other part of the world.

You can always see when a slip portion is attached to an express, by means of the peculiar arrangement of red and white lamps carried on the back. These may be seen on the tail of the slip in the Great Western Railway photograph on page 22, and are further explained in the little diagrams below. This is but one of many special precautions which must be taken in cutting into two halves an express train travelling at full speed.



TAIL-LAMPS USED ON SLIP COACHES

1. On the rear coach, when only one portion is being slipped.
2. On the back of the second slip portion, if there are two slips.
3. On the back of the third slip portion, if there are three slips.

Photo] [F. E. Mackay

BIRMINGHAM EXPRESS AT FULL SPEED, G.W.R.

RIDING WITH THE ENGINE-DRIVER

IF you are anxious to ride with the driver on the footplate of a big express engine on some famous train, I am bound to tell you in advance that you will not find it easy to arrange. A suitable piece of " paper " handed over to the gentlemen on the engine certainly will not make it possible. For the railway people are *dreadfully* particular ! If you make an application to travel on the engine, you will get a very nicely worded reply ; but it will really mean " Certainly not. In no circumstances whatever ! "

This is because " Safety First " must, on the railways, be the very first consideration, all the time. Nothing is allowed to distract the driver and fireman from their most responsible duties. So you must just let me tell you, as best I can, what it feels like ; I am one of those fortunate people who have what are called " satisfactory reasons " for wanting to accompany the driver, and sometimes I am allowed to do so.

You do not put on your best suit to ride on the engine. Personally, I always wrap myself up as well and thoroughly as I can in the oldest

clothes, and cover up all my face except enough to see and breathe through; it leaves less to be scrubbed when the ride is over! The big driver's shelter, or "cab," rushing through the air at speed, makes a strong suction, and so the smoke and steam from the chimney get sucked back into the cab, especially when you are running through tunnels, depositing itself freely over the occupants.

Neither is the footplate a place for nervous or delicate people. To those unaccustomed to it, the first necessity is that of holding on tight, as the shaking up that you get is tremendous. You sometimes feel as though the engine would shake herself to pieces before the end of the journey! An engine is not "sprung" like a dining-car; and then in addition you have all the swaying that is produced by the pistons moving to and fro, and the constant swinging round of the heavy parts of the machinery.

And now what about the crew on the engine? What has the fireman to do? A great deal more than you might think. Firing does not simply consist in opening the fire-hole door, and throwing in shovelsful of coal just anyhow, now and again. The locomotive boiler has to produce steam at a quicker rate than any other type of boiler that you could name, of equal size; and the firing must be carried out quite scientifically, if the engine is to do her work properly. This means dropping the coal in just the right position on the fire-grate, so that the draught may come up easily through the fire, and the coal burn through properly.

Then the quantity of coal to be handled on a long journey is nothing to be despised. When last I travelled on the engine of the famous Great Western "Cornish Riviera Express" from London to Plymouth, the fireman shifted some three and a half tons of coal from the tender on to the fire in the space of a little over four hours—a perspiring job indeed! The fireman has also to see that the boiler is properly supplied with water, and many are the anxious glances he

By courtesy] [G.W.R.

ON THE FOOTPLATE OF A GREAT WESTERN EXPRESS ENGINE

The driver has hold of the regulator handle. Above his hand (looking rather like a pepper-pot with a handle) is the ejector by which the vacuum brake is applied. Immediately behind his back is the wheel and screw of the reversing gear. The fireman is shooting coal through the fire-hole door; above his neck is the boiler water-gauge, and in the top left-hand corner of the cab is the pressure-gauge; behind the fireman's back are seen lubricators, serving important parts of the motion.

may be seen to direct towards the water-gauge and the pressure-gauge during the journey.

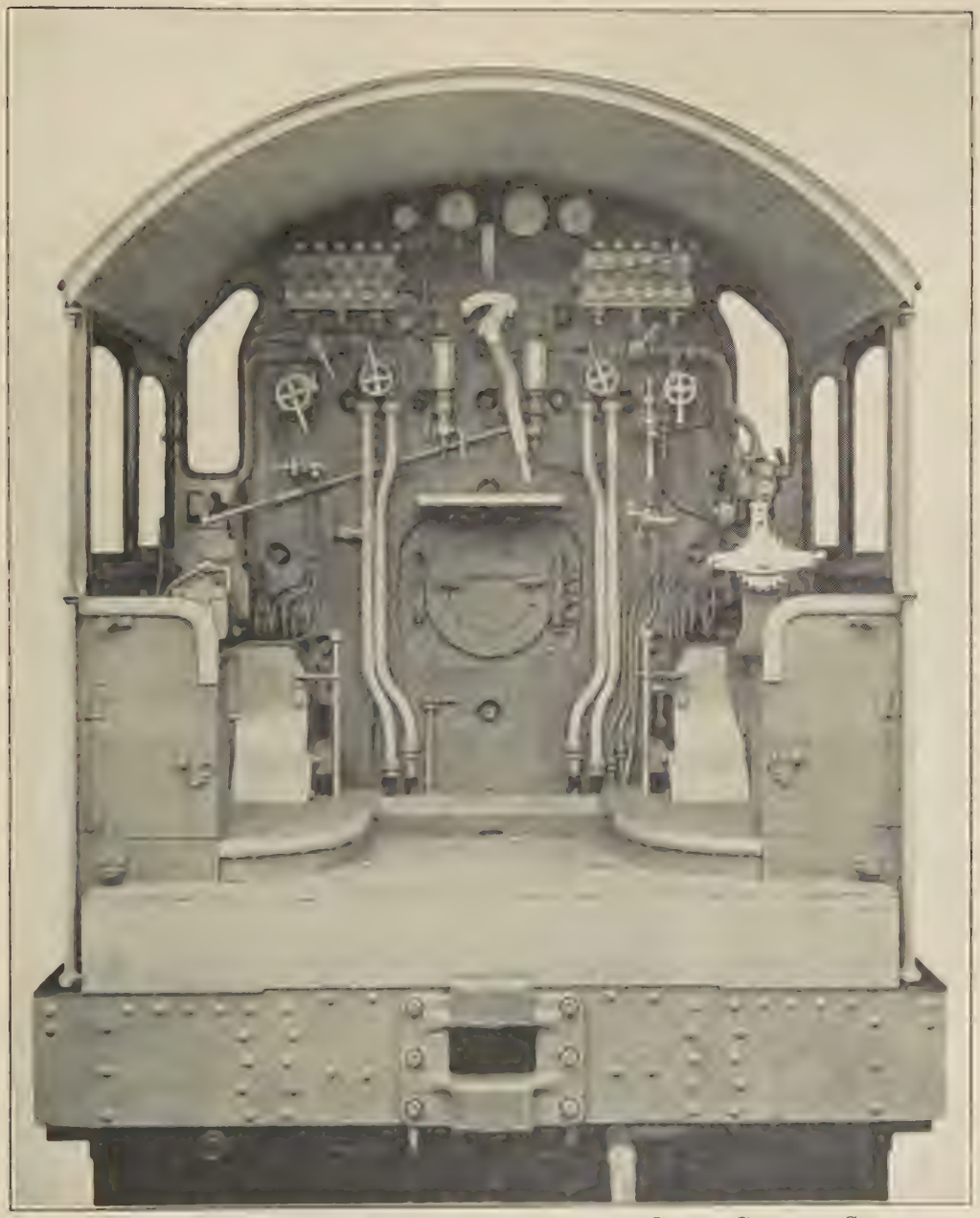
And then there is the driver. His is a more scientific task still. He has to see that the steam produced by the efforts of his fireman is put to the best use. The big handle which his hand rarely leaves is the regulator ; it controls the passage of the steam from the boiler down to the cylinders. Then he frequently controls the use of the steam in another way, by what is called the valve-motion or "reversing gear."

It is through the slide-valve or piston-valve that the steam actually enters the cylinder, and these important valves both control the admission of the steam, and also cut it off at exactly the right moment. By the valve-motion the driver can regulate the point at which steam is " cut off " ; for the rest of the forward motion of the piston the steam expands, ere it is thrown out of the chimney in the " puffs " that are so familiar to you. When the engine is starting, the driver uses a " late " cut-off ; as it gets into speed, and the boiler can no longer supply steam so fast as to fill the cylinders at every revolution of the wheels, he brings the cut-off back, making more and more use of the expansive possibilities of the steam in the cylinders.

So the whole science of driving consists in manipulating the regulator and the valve-motion in such a way as to meet every change of gradient, or load, or of the booked speed of the train. One needs to watch a driver at work, especially over a hilly stretch of line with a fast and heavy train, to realise how much brain-work is necessary for driving. And then, equally or even more important, there are all the signals to be watched ; the driver dare not neglect a single one.

All this means, as you can readily understand, a most intimate acquaintance with every yard of the road over which the driver has to travel. And this brings me to the way in which the footplate is reached. There is no " Royal Road " to driving. The first stage of

The "Southern Belle" Express, Southern Railway.
From photo by F. E. Mackay



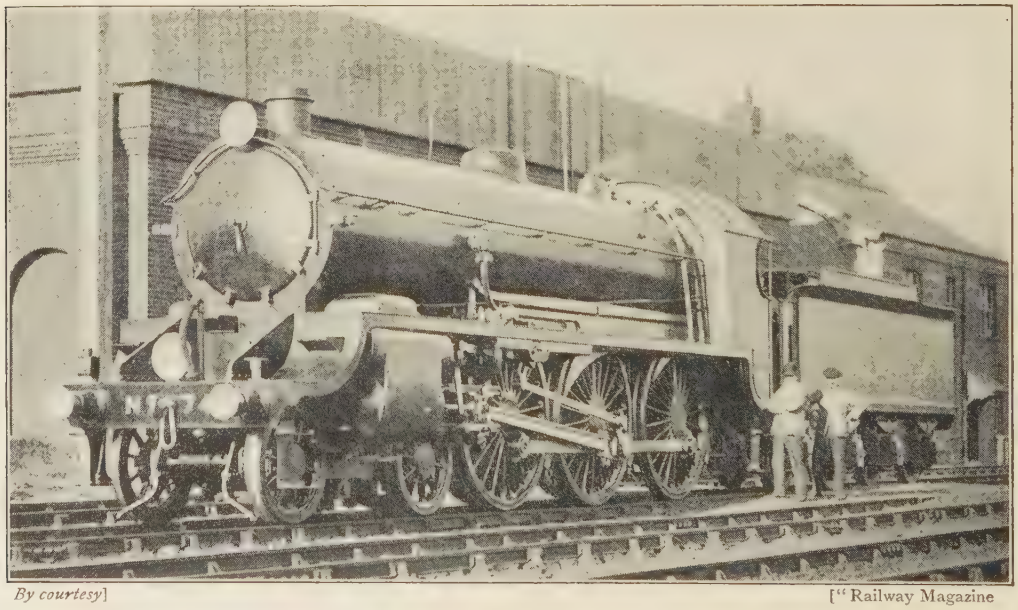
CAB OF A MODERN L. & N.E.R. EXPRESS ENGINE, GREAT CENTRAL SECTION

Regulator handle in centre, with fire-hole door below; reversing gear on right-hand side, with vacuum brake ejector above; water-gauges each side of regulator; sight-feed lubricators at top right and left corners of cab, with pressure, brake and superheater gauges between; the four small wheels each side of regulator work the injectors, admitting water to boiler.

training is the humble work of cleaning engines, inside and out, a job begun in boyhood's days. After some years at cleaning, during which the boy is learning how an engine is built, there comes firing, first on a little shunting engine, then on goods trains, then slow passenger and lastly express passenger trains.

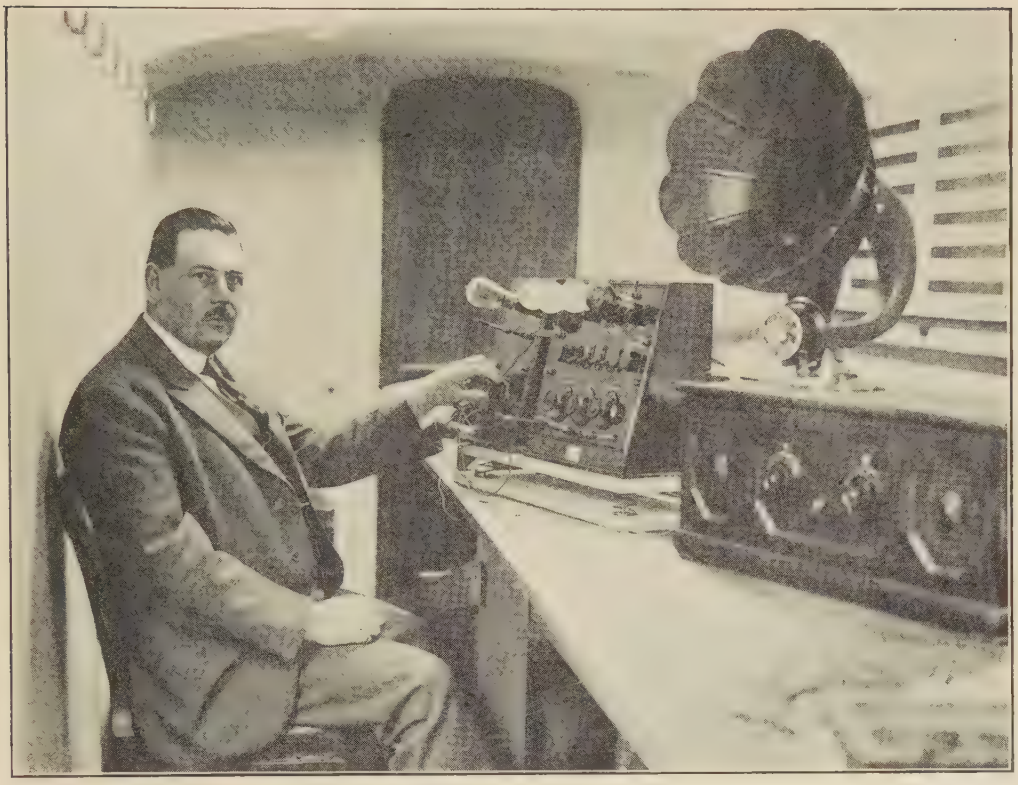
Then, ere the fireman can take his place as driver, there is a strict examination on what he knows of the engine, and if he comes through, as well as through the rigid tests of health and eyesight that take place from time to time, at last he takes his place " in command " on the footplate. Again he has to rise slowly, from the shunting engine until he reaches ultimately the footplate of the big express locomotive.

The pictures on pages 27 and 29 give you a good idea of the inside of the shelter, or " cab," in which the driver and fireman work. Cabs in these days are much bigger and more comfortable than they were; extended roofs, to keep out the weather, side-windows, and even seats are often now provided.



By courtesy] ["Railway Magazine

READY FOR THE ROAD—A SOUTHERN RAILWAY GIANT AT EXETER



LISTENING-IN ON THE NIGHT EAST COAST "SCOTSMAN"

SOME MODERN WONDERS OF TRAVEL

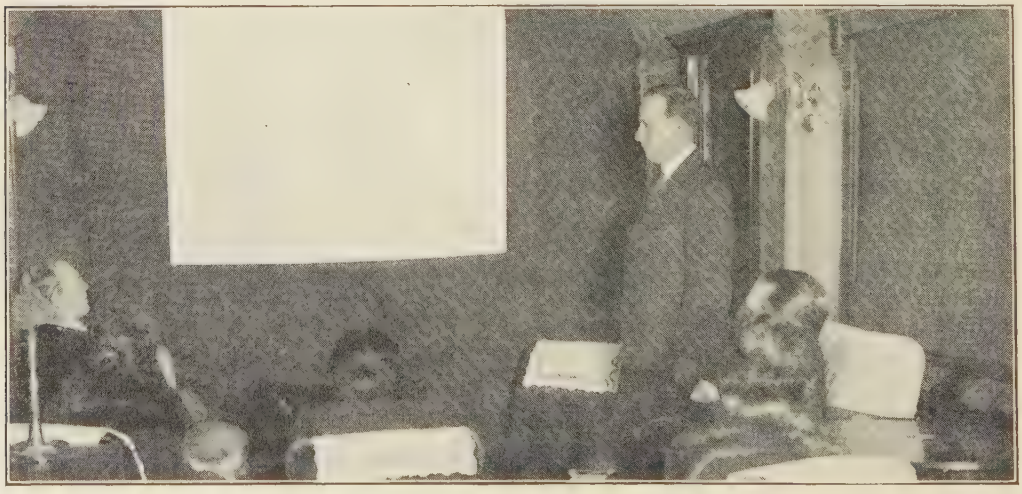
(Photos by courtesy of L. & N.E.R.)

ONE of these days it is probable that wireless will play a very important part in the working of our railways. It may be that the very movement of the trains will be controlled by wireless means; such methods, if perfected, might well make collisions on the railway impossible. Just by way of an experiment, the London and North Eastern Railway recently conducted some tests in conjunction with the Radio Society of Great Britain, on a night East Coast express travelling from King's Cross to Aberdeen. A good deal of the apparatus used you can see in this picture, which shows the five-valve receiving set employed, and in another part of the brake-van in which the tests were conducted there was a transmitting set,

on which messages were sent out during the journey. The aerial was fixed up inside the roof of the coach, and an " earth " was effected through the steel wheels of the vehicle to the steel rails of the track.

A special call sign—" 6ZZ "—was allotted for the occasion to this travelling wireless station. Most interesting tests were carried out all through the night, and the possibility of " wirelessing " to and from a moving train, even at speeds which sometimes exceeded seventy miles an hour, was clearly shown. It was noticed that when the train was passing through tunnels and deep cuttings, the signals could barely be heard ; and wooded country, the nearness of water or beds of iron ore, and other factors, all served to make differences in the clearness of the " reception."

Another experiment illustrated at the bottom of this page, was also made by the L. & N.E.R. recently, in running a cinema show on the " Flying Scotsman." This was given in a specially fitted coach, in which were seats for some thirty people. One " show " was given between King's Cross and Grantham, and then, after the passengers had been allowed time to go along to the restaurant car for lunch, another long picture was shown between Grantham and York.



A Cinema Show on the " Flying Scotsman "

LETHBRIDGE VIADUCT, ALBERTA

CROSSING A CONTINENT

THE STORY OF THE CANADIAN PACIFIC RAILWAY

(All photos by courtesy of the C.P.R.)

ONE of the most remarkable railways in the world is the great Canadian Pacific, whose services girdle over one-half of the globe. Not only does it work 14,500 miles of line in Canada, from east right across to west, but it also runs its own steamer services across the Atlantic from England to Canada, and again across the Pacific from Vancouver to China and Japan.

The history of its construction, if only I had time to tell it, is a fascinating tale of the overcoming of difficulties, and of the obstacles placed in the way of the builders by Nature. Some of the line through the wild country on the north side of Lake Superior, in Southern Ontario, cost as much as £140,000 per mile; in fact, a stretch of only 200 miles ran the builders into two and a half million sterling of money. You will realise the kind of engineering that has been carried out as you look at these photographs. For example, the spidery Lethbridge Viaduct above is 47 feet over one mile in length, and no less than 314 feet above the bed of the river below, at its highest point; 12,200 tons of steel were used in its construction.

The "Trans-Canada Express," Montreal to Vancouver

Then, as the line stretches out further west, it reaches the vast natural barrier presented by the Rocky Mountains, disputing its passage to the west coast of Canada. After leaving the western city of Calgary, the line climbs gradually up the valley of the Bow River, through a natural gateway in the mountains known as "The Gap," until it reaches the summit level of 5329 feet above sea-level, in the Kicking Horse Pass. This is called the "Divide"; it is the top of the watershed, where the waters of the mountain glaciers split to run eastwards to the Atlantic, and westwards to the Pacific Ocean.

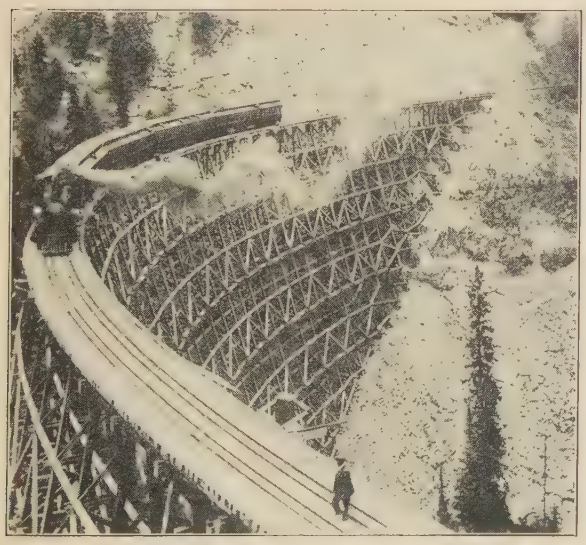
From here the line has to drop sharply into the deep valley of

Freight Yards at Winnipeg

the Columbia River, and from Hector down to Field, in the early days of the railway, the "Big Hill," as it was called, involved a fall of 952 feet in no more than 4 miles, which meant a fearful expense in operation, owing to its steepness. Twenty-five years later a deviation was made, and some remarkable spiral tunnels, like those of Switzerland, now reduce the steepest part of the line from a grade of 1 in 22 to 1 in 45—a big difference.

Snow-shed in the Rockies

After the Rocky Mountains comes the parallel range of the Selkirks. The engineer, Rogers, found a narrow passage for the railway through Rogers Pass, but this meant a climb of 1768 feet in the 67 miles from Golden to the summit, 4309 feet above the sea, followed by a drop of no less than 2857 feet in the next 22 miles beyond the pass. The heavy grades that were involved by these big differences in levels have recently been overcome by the driving of the Connaught Tunnel, which figures in the coloured plate at the beginning of this chapter. This tunnel is the longest in America, and its five miles were bored in the record time of 704 days. The cut-off has reduced the height to which



Old Trestle Bridge

FOUR TUNNELS IN THE FRASER RIVER CANYON

the line has to climb in the Selkirks by 550 feet, has shortened the distance by $4\frac{1}{2}$ miles, and has, of course, very greatly eased the grade, so that the two and a half millions of money spent on its construction has been well worth while.

Incidentally, the snow problem in these wild mountain surroundings is as serious as it is in countries like Switzerland, and probably more so. On page 35 you see one of the many "snow-sheds" which have been built at points where avalanches are known to be frequent, in order to throw the snow clear of the line as far as possible. The kind of engineering which had to be undertaken along the banks of the Fraser River, on the way from

A Country Station in Canada

the Selkirks to the west coast, is clear in the photograph opposite, which shows four tunnels and a bridge over the river in a bare half-a-mile of railway. It is all the more remarkable to realise that the original line, from Montreal to Vancouver, 2900 miles, was completed in the short space of 15 years, despite the engineering difficulties I have described. Much of the distance, however, was across the flat prairies of Manitoba, Saskatchewan and Alberta, where construction was comparatively easy.

Windsor Station, Montreal—The Train-Sheds

The mainstay of the traffic over the Canadian Pacific Railway of to-day is the grain produced in those vast areas of prairie. The amount of that traffic you may understand by looking at the photograph on page 34 of the enormous freight yards at Winnipeg—the capital of Manitoba and the central point on the line—where no less than 120 miles of sidings have been laid. Present-day passenger travel on the C.P.R. is seen in the picture of the luxurious " Trans-Canada Limited " express, which leaves Montreal every day at 6 o'clock in the evening, and reaches Vancouver, on the other side of the Continent, at nine in the morning four days later.

The pictures of Canadian stations will interest you ; you see how, in a country where there are exceedingly cold days in the winter, people do not wait for their trains on the platforms, but indoors, and this probably explains why the interior of many of the biggest stations in America and Canada are so beautifully designed, as in the photograph below.

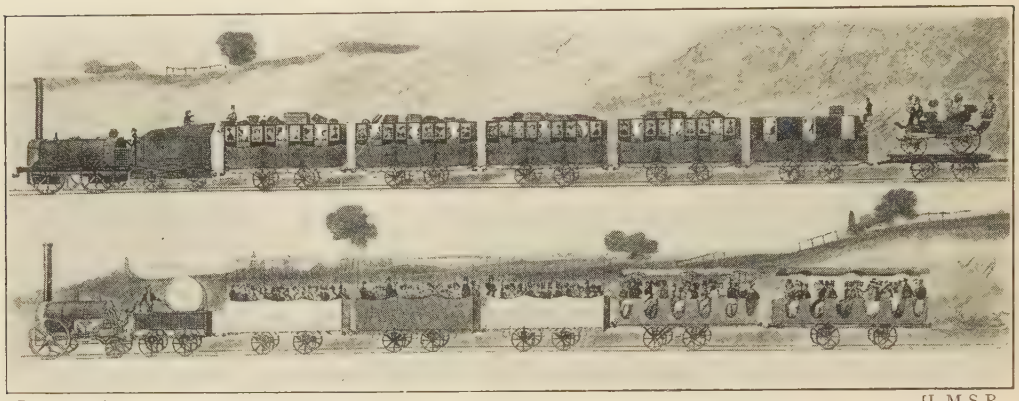
Interior of Windsor Station, Montreal

THIRD-CLASS PULLMAN CAR

RAILWAY COACHES—PAST AND PRESENT

A COMPARISON of the photograph above with the picture at the top of the next page, forcibly reminds us how railway travel has been revolutionised in the space of some ninety years. On the London and Birmingham Railway, in 1837, first-class passengers had covered coaches in which to ride, while second-class people had nothing more than a canopy over their carriages, and the third-class travellers were not much better off than they would be in cattle-trucks. Nowadays, there is scarcely an express train running in the country which does not include either restaurant cars or Pullman cars in its formation, for both first-class and third-class passengers.

The carriages of early days were carried on four wheels only, and were probably only about twenty-five feet long. From four wheels we progressed to six wheels, and from six wheels to eight wheels. Then the principle of carrying the coaches on " bogies " was introduced, whereby each end of the eight-wheeled coach rests on small four-wheeled trucks, or " bogies," pivoted in the centre, and this enables the coach, like the front end of an express engine, to swing freely round the curves, especially when the train is running at speed, so making for smooth riding. Some of the longest and heaviest coaches, as the Pullman car at the head of this chapter, are carried on six-wheeled bogies. But the practice over here is generally



By courtesy] [L.M.S.R.

WHAT PASSENGER TRAVEL WAS LIKE IN 1837

to stick to the four-wheeled bogie for coaches, the longest vehicles so running in the country being the 70-foot and 73-foot coaches of the Great Western Railway.

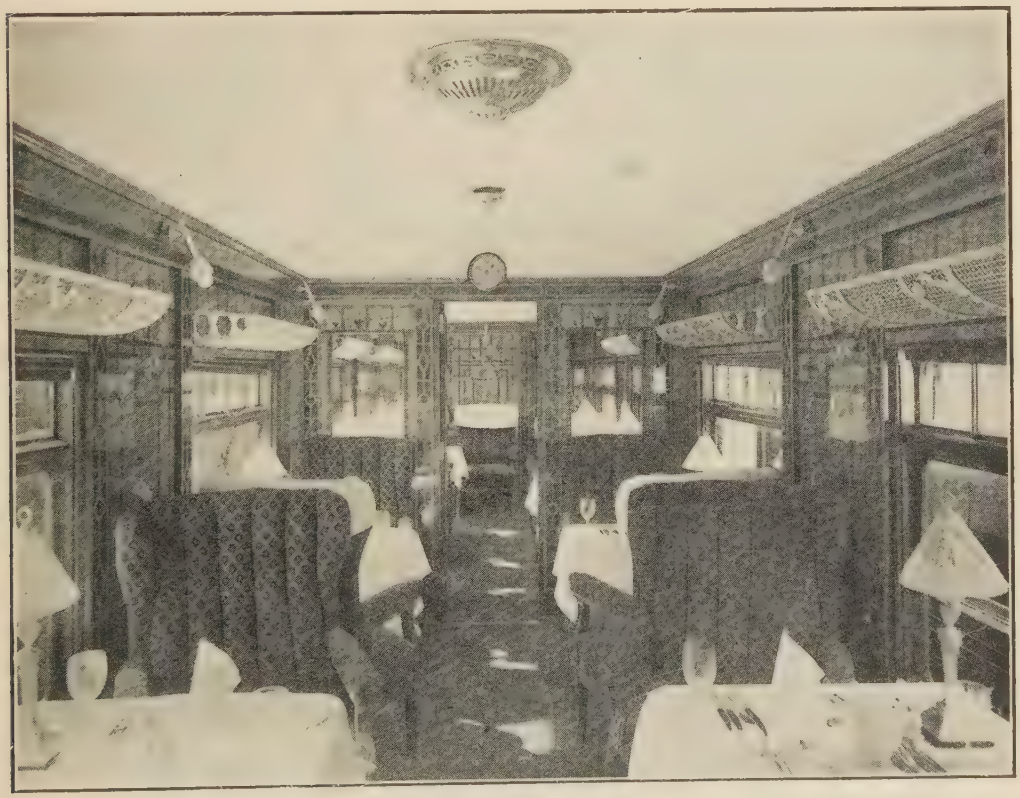
The latest way of building carriages is that illustrated at the top of page 44, which shows a set of "articulated" coaches on the London and North Eastern Railway. In this arrangement, the ends of adjacent carriages are carried on only one bogie, so that instead of the three vehicles—first-class dining-car, kitchen car and third-class dining-car—being carried on six bogies, only four are used, and the weight of the "set" is correspondingly reduced. There are various kinds of articulated coaches now at work on the London and North Eastern, including dining, sleeping and corridor carriages, old six-wheeled coaches rebuilt as articulated sets, and many complete

By courtesy] [L.N.E.R.

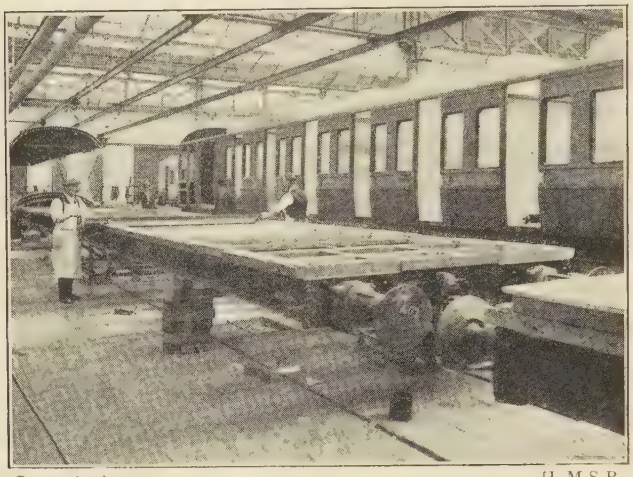
THE FIRST BRITISH DINING CAR, 1879

suburban trains. But you cannot uncouple any part of an articulated set, of course, and use it by itself !

In carrying suburban passengers, it is the maximum possible seating space that is wanted in the minimum of train weight, so that the engines shall be able to make smart starts from their many stops, and get up speed quickly. A suburban train of the Great Eastern section of the L.N.E.R.—which probably has to handle a denser suburban traffic with steam locomotives than any other railway in the world—consists of eight bogie carriages and seats 828 passengers, six a-side in the third-class and second-class, and five a-side in the first-class. The average weight of coach is thus only about quarter of a ton to every passenger conveyed, when the



Interior of First-class Pullman Car

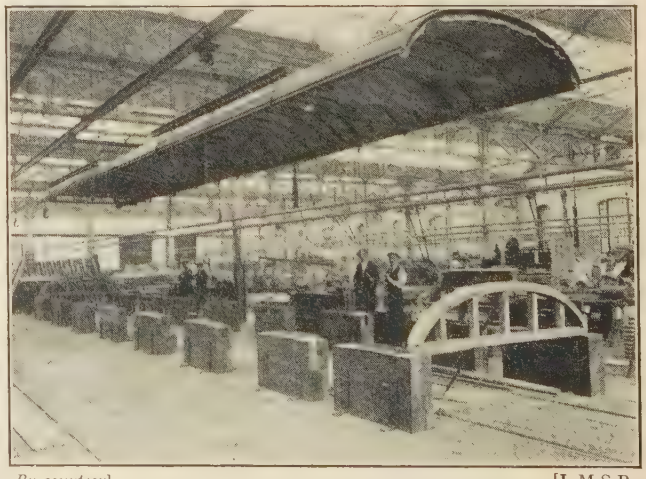


By courtesy] [L.M.S.R.

COACH-BUILDING—THE FRAME

train is full. The French have tried to solve their suburban problem round Paris, on one line at least, by using " double-deck " carriages like tramcars, as shown on page 46. But we have not sufficient room under our bridges to do the same here.

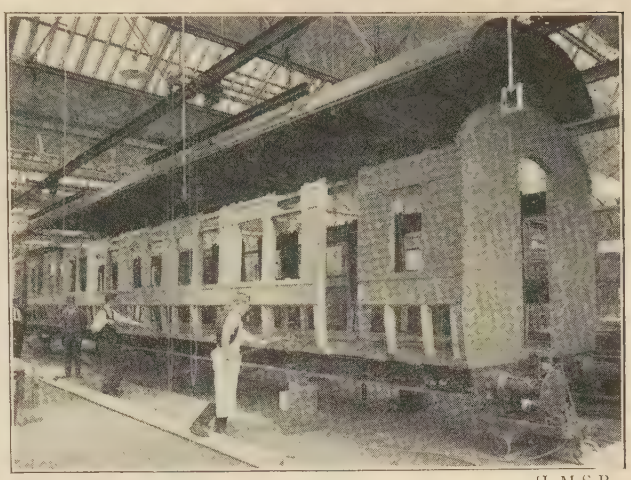
The case is very different with the main line coaches, however. Corridors and lavatories have all cut something away from the seating space of the coaches in which they are installed ; and dining, sleeping and Pullman cars are even more costly in this respect. For example, the Pullman car, whose interior —like a drawing-room on wheels—is shown on page 41, seats only twenty-one people, and weighs rather over forty tons ; this means two tons of coach weight to every passenger conveyed. You will thus understand why extra fares have to be paid for the luxury of Pullman travel. The name " Pullman," by the way, originated on the other side of the Atlantic, where an American named Pullman thought there would be a ready market for specially comfortable travel at special prices, and started



By courtesy] [L.M.S.R.

COACH-BUILDING—THE ROOF

to introduce the carriages which bear his name. In America and Canada Pullman cars correspond to our first-class over here, and are in universal use.

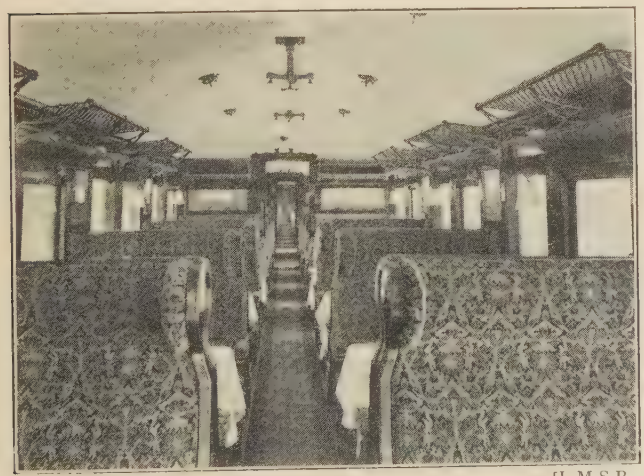


By courtesy] [L.M.S.R.

ASSEMBLING THE COACH

It was probably the Pullman car that introduced the demand for "open" coaches on our own main line services. Some railways, like the London, Midland and Scottish, are now building open cars very extensively, and you find them on nearly all the chief L.M.S. trains to-day.

The whole course of the building operations at Derby Works, by what is called "mass production," are shown in the interesting series of pictures on these two pages. First of all you see the frame of the coach, and then, in the second picture, the "jigs," on which the roof has been made, with the roof itself raised in the air ready for the assembling of the coach. This is to take place in the background of this picture, where the frame and the two sides are waiting ready. The third picture of the series shows the sides and ends of the coach being cramped on



By courtesy] [L.M.S.R.

THE LATEST L.M.S. TYPE COACH COMPLETE

LATEST " ARTICULATED " DINING CAR SET, L.N.E.R.

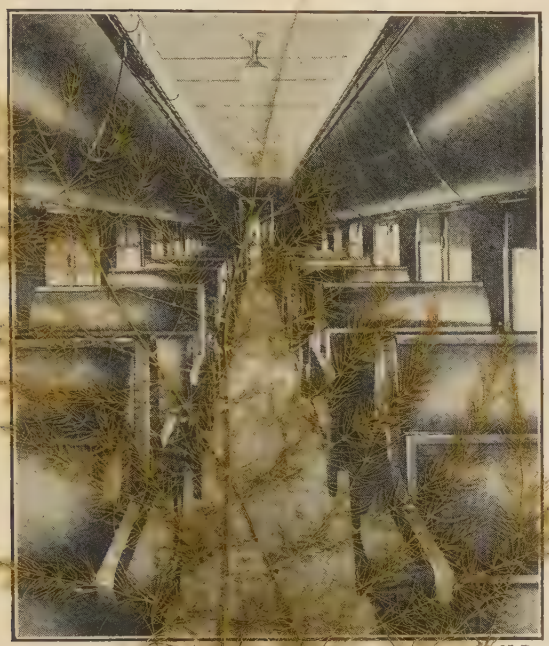
to the frame, and the roof about to be lowered into position. The next operation will be the fitting of the inside, and the dropping of the whole vehicle on to the bogies, when it will become the beautiful carriage shown in the last photograph of the four.

The open type of coach is universal on the Continent of America, and on page 45 you see a typical Canadian " Colonist " car, corresponding to our third-class over here. In this class of vehicle, the seats are so arranged as to make beds at night, and the two sides of the roof let down to make upper berths also, so that beds are provided for everyone on the train. This is essential on such long journeys as those which cross America, taking several days in succession. In Great Britain sleeping accommodation is provided for first-class passengers only, but the journeys are much shorter. No sleeping-cars could be more comfortable than the latest in this country, which are provided with real beds, each in its own separate room, and are furnished with every imaginable comfort.

By courtesy [L.N.E.R.

MAKING ELECTRICITY ON A RAILWAY COACH

There are two photographs on page 47 which



By courtesy] [C.N.R.

CANADIAN "COLONIST" CAR

give some interesting details of how coaches are designed. In the foreground is the big "gangway" through which you walk when you are on the way to the dining-car. Under the gangway you can see two pipes. The one to the left is the very important brake connection; joined up to the corresponding pipe on the neighbouring coach, it makes a through communication from the engine right through to the last coach on the train, whereby the driver, when he applies the brake, applies it not only on his engine, but also on every carriage behind him. This is why passenger trains are able to make such rapid stops, as compared with goods trains.

There are two types of "continuous" brake in general use; the one shown in these pictures is the "vacuum" brake, whereby a vacuum in cylinders under each vehicle is the "reservoir" of

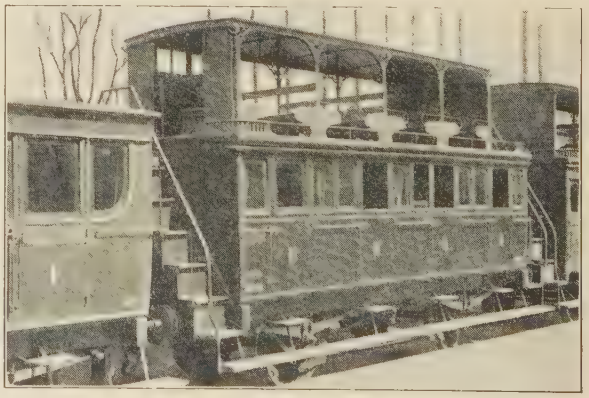
By courtesy] [C.P.R.

STANDARD CANADIAN SLEEPING-CAR

Suburban Train, L.N.E.R. (Great Eastern Section)

power, and the destruction of the vacuum by the driver, who opens a suitable valve, applies the brake. The Westinghouse brake is also in common use ; in this case power is supplied by compressed air.

The other pipe, on the right-hand side, carries the steam which warms your compartments in the winter ; it also comes direct from the engine. In the old days there used also to be a cord running along outside the coaches, just above the doors, connected to the engine whistle, so that a passenger could give warning to the driver if anything was wrong, but this is now replaced by the handy chain inside the compartment. Pulling this partially applies the brake on your own carriage, and also sounds a shrill whistle at the end of the coach, and causes

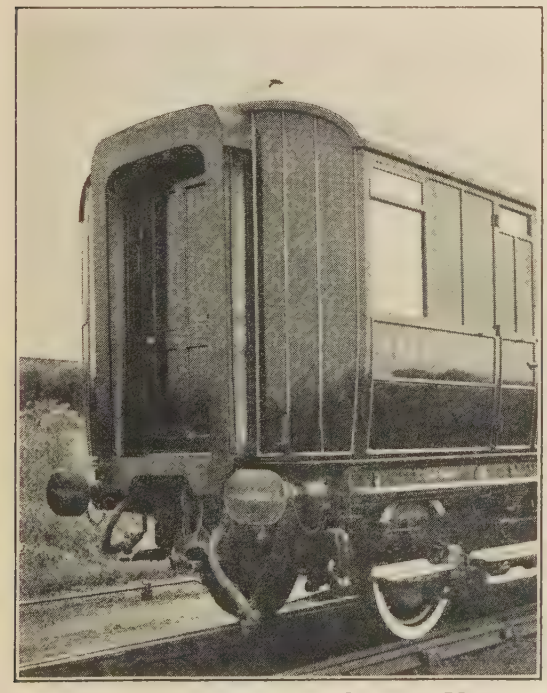


A " Double-deck " French Suburban Coach

a little red signal to project outwards; in this way the coach concerned is instantly found.

The other, and most important end fitting of all is, of course, the coupling. In the earliest days, carriages were just connected by chains, as are so many of our goods wagons today, and starting and stopping were jerky and unpleasant affairs for the passengers. Then the chains gave way to the screw coupling, which enabled the distance between the coaches to be adjusted until the buffers just nicely touched, and the jerking was done away with. Now we have gone further still than this, with the automatic coupling, first used here on the East Coast trains of the L.N.E.R. in 1898.

Automatic Coupler in Position
L.N.E.R. Vestibuled Coach



Automatic Coupler Out of Use
L.N.E.R. Vestibuled Coach

In the lower of these two photographs the coupler is swung out of position, so that the ordinary screw coupling can be used on the hook (as is necessary when one of these coaches has to be coupled up to a vehicle without the automatic coupling). It is in shape like a hand partly clenched; and when in correct position, as in the upper picture, it meets the coupler of the next

coach, the two literally " shake hands "—and do not leave go again ! Another valuable outcome of this type of construction, is that these automatically-coupled coaches have been proved on several occasions to keep exactly in line when a train has been derailed, instead of the dreaded telescoping of one coach into another, which has been the source of so many deaths and injuries in railway accidents.

An alternative and ingenious way of providing against telescoping was that adopted on many of the coaches of the late Great Central Railway, and illustrated below. Here the coaches are fitted at the ends with heavy castings, shaped like teeth, to bite solidly into each other in the event of an accident.

Another interesting detail of coach equipment is seen in the photograph at the bottom of page 44, which shows how coaches make their own electricity for lighting. A belt off the axle drives the dynamo in the foreground, and the electricity from this is taken to accumulators under the coach, where it is stored for use as required. In the latest restaurant cars of the London and North Eastern, this electricity is being used for cooking also, instead of gas.

Corridor Train with " Anti-Telescoping " Appliances, L.N.E.R.

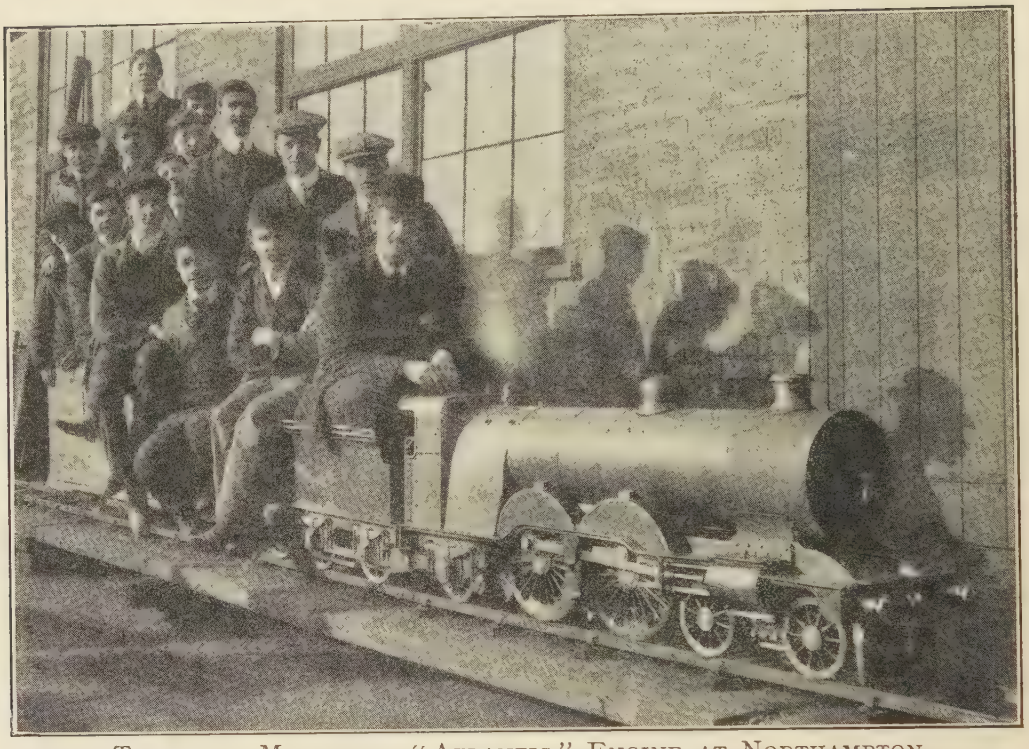
THE TINIEST ENGINE THAT EVER PULLED A TRAINLOAD OF PASSENGERS

RAILWAYS IN MINIATURE

(All photographs by W. J. BASSETT-LOWKE)

THERE are few things of more fascinating interest than miniature railways. Many of you, no doubt, have your own "private" lines, laid in temporary fashion round the dining-room floor, or more permanently in the attic or even in the garden. But these are railways on a very, very tiny scale; and I do not suppose you have ever experimented in the way of trying to induce your model engine to pull *you!* For all that, it is surprising to realise what has been done in the matter of passenger-carrying on the most miniature of gauges. Here is a picture of a little engine which, at the Model Engineer Exhibition of 1924, succeeded in pulling no less than three full-grown people, and on a track whose gauge was no wider than 2 inches!

And what about the second picture in this article as a test of miniature locomotive capacity? You see some fifteen hefty North-

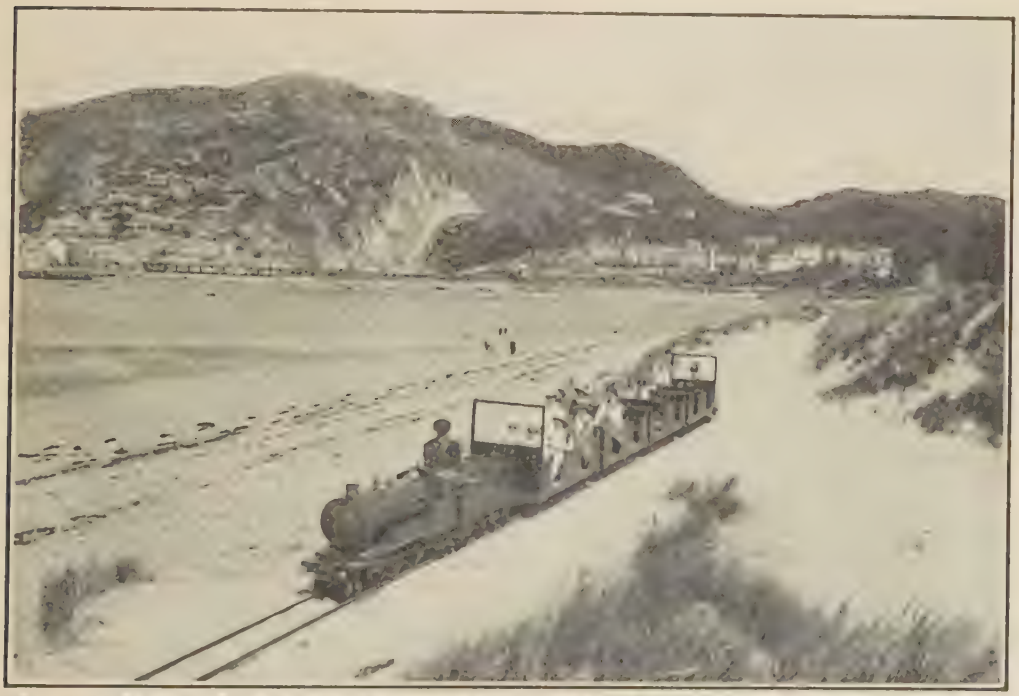


TESTING A MINIATURE "ATLANTIC" ENGINE AT NORTHAMPTON

amptonshire men and boys trying the results of their handiwork at the well-known Bassett-Lowke model railway works. The gauge on which this engine runs is only 9½ inches, and the scale is only one-sixth of full size ; yet the weight she is pulling cannot be far short of a ton ! Actually this engine is an exact model of one of the familiar Great Northern "Atlantic" locomotives, and you can see it at King's Cross Station, near the bookstall, on No. 10 platform.

But I am more concerned with real passenger-carrying railways on a very small scale. The tiniest passenger railway in the world is probably the Eskdale Railway in Cumberland. The gauge—that is, the distance between the rails—is only 15 inches. If you have not yet seen this unique railway, you have probably seen short lines of a similar kind in the pleasure gardens at Rhyl, Southport, Black-

ROUNDING "CAPE HORN" AMONG THE MOUNTAINS OF CUMBERLAND—THE ESKDALE RAILWAY



ON THE SANDY SHORES OF CARDIGAN BAY—THE BARMOUTH & FAIRBOURNE RLY.

TWO VIEWS ON 15-INCH GAUGE MINIATURE RAILWAYS

A Heavy Load

pool or elsewhere, laid down for amusement purposes, and worked with scale model express engines. But the Eskdale Railway, although worked in just the same way with scale model engines, is a real business line ; it forms, indeed, the only means of communication up the valley of the Esk, and is 7 miles long.

In the summer-time, when the line is a centre of attraction for many miles round, passengers are carried in little open cars, as you see, each holding eight people, two abreast. Sometimes train-loads of a hundred people and even more have been made up. For wet weather and for the winter, however, there are some closed cars ; needless to say, there is no room to spare inside, although, if you double yourself up very carefully as you get in, it is possible for you to avoid banging your head on the roof !

A Leafy Tunnel on the Eskdale Railway

Engine Headlamps and Discs on the Southern Railway.

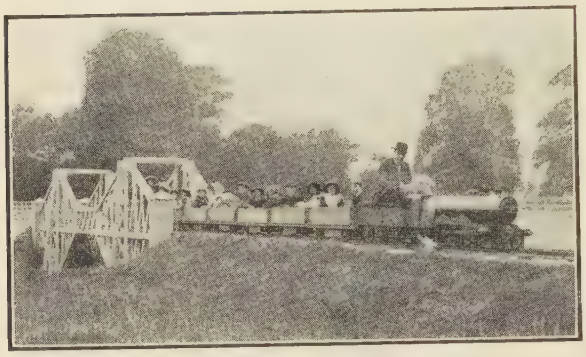
Just to show what could be done on so narrow a gauge as 15 inches, a sleeping car was actually built to run on the line ! It has four berths, two on one side and two on the other—an " upper " and a " lower " berth in each case —and I believe it has been used as reserve sleeping accommodation for the staff on the Eskdale line when they have been very short of room.

" Colossus " on the Eskdale Railway
It is hard to tell that this is not the " real thing ! "

The engines are a beautiful copy in miniature of full-size machines. There are two types—the "Atlantic " and the " Pacific "—and it is the latter that is used for the heavy work. Although the engine " Colossus," which appears in several of the illustrations, only weighs, with her tender, some 3 tons all told, she has done some wonderful work. On page 55 you can see her under test on the private line of the Duke of Westminster at Eaton Hall, in Cheshire.

Inside an Eskdale Railway Coach

The " driver," by the way, is the writer of this book ; we succeeded in pulling a load of 17 tons on that occasion, and in coaxing a



CROSSING THE "FORTH BRIDGE"
STAUGHTON MANOR RAILWAY

speed of no less than 35 miles an hour out of this little machine. Seeing that "Colossus" is only planned to a scale of one-quarter full size, this speed was really equivalent to a "full-size" speed of something over 100 miles an hour! It was a very thrilling experience.

The driver, as you can see, sits in the tender of the engine, and he has to act as driver and fireman rolled into one, because he has no room for a companion. On such a line as the Eskdale, which has some very steep and awkward switchback gradients, working the engine is by no means an easy job, especially when a big load of passengers is being hauled for 7 miles on end. It is the simplest thing imaginable to get "stuck" for want of steam, and the constant curves in the road, such as the rounding of "Cape Horn," call for constant watchfulness.

There are quite a number of railways in the country with gauges of 2 feet and upwards. You have probably seen some of the "toy" railways in North Wales, several of which, as a matter of fact, are anything but toys. The Festiniog Railway, for example, which connects the slate-quarrying district of Blaenau Festiniog, in the

A REALISTIC STATION ON THE STAUGHTON MANOR RAILWAY

Welsh mountains, with the coast of Cardigan Bay, at Portmadoc, is a very busy line indeed. It has been laid out with a perfectly even gradient from the quarries down to the sea; so it is possible to run long trains of slate to the coast for shipment, without any engine being used at all. The engines then haul the empty wagons back to Blaenau Festiniog, to fetch the next load.

A Test Load of Coal, Eaton Hall Rly.

Curious double-ended locomotives of the Fairlie type are used on this railway. They are really like a couple of engines arranged on one frame, and under the control of only one driver and fireman. The cylinders and the motion are mounted on swivelling trucks or "bogies," under each end of the engine. This arrangement makes it possible to build a powerful engine on a small scale whose weight is spread out over a good length of track, but which yet readily adapts itself to the curves.

The possibility of laying very sharp curves is one of the great advantages of a narrow-gauge railway. In mountainous country a narrow-gauge line can be laid in such a way as to "hug" the steep hill-sides, without tremendous expense in cuttings and embankments, bridges and tunnels. The cost of track, engines, carriages and wagons is much less than those of the standard gauge, too, on account of their smaller scale.

A Pretty Corner, Sand Hutton Railway

BOURNEMOUTH EXPRESS, SOUTHERN RAILWAY
The engine is carrying the " head-code " for the Southampton route ; the number on the disc below the chimney is the number of the train.

ENGINE HEADLIGHTS AND DISCS

(All photographs by F. E. MACKAY)

IN nearly all the pictures in this chapter you will notice that the engines are carrying curious round sheet steel " discs " in front, some painted white, and others having crosses or other devices painted on them. It is hardly necessary to say that the discs are not used for decorative purposes. Generally speaking, by the way that they are painted, and also the way in which they are arranged in front of the engine, they indicate the route that the train is going to follow. Each engine has its own supply of discs of different kinds, and it is the fireman's duty, before the train starts, to see that the right discs are in their right places, so that signalmen and others, as the train approaches, may know readily where it is going. This is most important on such a system as the Southern Railway, which has so many terminal stations in London, and so many ways of reaching most of the towns that it serves by means of its network of lines.

BRIGHTON PULLMAN TRAIN, SOUTHERN RAILWAY
Carrying the old discs (now done away with).

In the old days, many different kinds of discs were used — round, oval, square, and diamond-shaped, and with various spots, crosses and other designs in different colours painted on them. The difficulty was, however, that this great variety by day could not be distinguished at night, when the only coloured lamps the engine can carry are green and blue, in addition to white. So in these days the "codes," or arrangements of discs, are being simplified as much as possible, and the discs used are being cut down to plain white, white with black cross, or black or green centre, for which at night a green lamp is carried, and white with a blue centre, indicated at night by a blue or purple light.

The other main lines of railway, whose main routes are not, perhaps, so complicated, do not trouble to carry discs, but make their indications by means of the ordinary headlamps, unlighted in the daytime and lighted by night. No attempt is made to indicate routes at all, generally speaking; the headlamps just show

WEST OF ENGLAND EXPRESS, SOUTHERN RAILWAY
The two white discs form the "Salisbury" line code, and the black centre disc indicates a "special train."

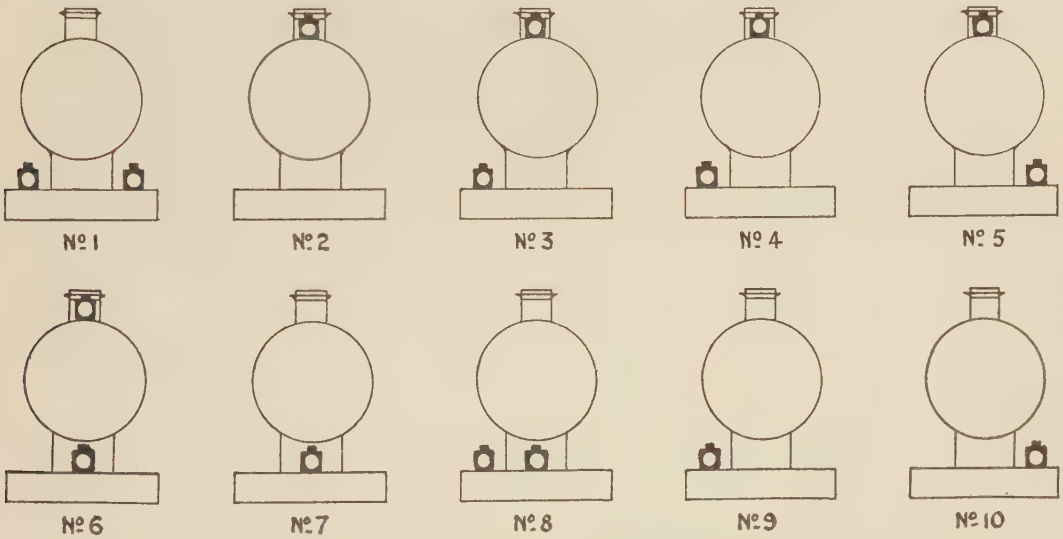
CLACTON & WALTON EXPRESS, LONDON & NORTH EASTERN RAILWAY
The " express passenger " head code is indicated with the white discs over each buffer.

the " class " of each train. There is, first of all, the familiar pair of lamps, one just over each buffer on the front of the engine ; this shows that the train is an " express passenger." Then there is the single headlamp, at the base of the chimney or just

THE " FLYING SCOTSMAN," LONDON & NORTH EASTERN RAILWAY
The engine is carrying " express passenger " headlamps over each buffer.

below; this indicates an "ordinary" or "stopping passenger" train.

So the list goes on, through the various kinds of goods trains, empty carriage trains, "light engines" (engines without any coaches behind them) and so on. There is not space to detail them all here, but the little series of diagrams shown on this page may help you to recognise the various kinds of trains in future. On the North British



STANDARD BRITISH CODE OF ENGINE HEADLAMPS

1. Express Passenger Train. 2. Ordinary (Stopping) Passenger Train. 3. Empty Passenger Train. 4. Express Fish, Fruit or other train carrying "Perishable" traffic in vehicles fitted with continuous brakes. 5. Express Goods Train carrying "Perishable" traffic in ordinary goods wagons, Class "A." 6. Express Goods or Cattle Train, Class "B." 7. Light Engine, or Engine with Brake-Van only. 8. Through Goods Train. 9. Through Goods Train making intermediate stops. 10. Ordinary Stopping Goods Train.

Railway the headlamps are specially painted white, so that they may be seen at a distance.

The positions principally used for the lamps are four—at the base of the chimney, over each buffer and in the middle of the buffer-beam, just over the couplings. Some railways, however, have additional "lamp-irons." On the South Western section of the Southern Railway discs and lamps are carried on both sides of the

THE WEST COAST "SCOTSMAN" ON THE CALEDONIAN SECTION, L.M.S.
Notice the route indicator at the foot of the engine chimney.

boiler—or, really, on what is called the "smoke-box." You see these positions in use in the photograph at the beginning of this chapter, showing a Bournemouth express, which carries its three white discs in a triangle.

The late Caledonian Railway had a head-code of its own, quite different from the codes in use elsewhere. The lamps were not carried on the front of the engine, but on each side of the driver's cab, so that only two positions were available. But for route-indicating by day, each engine was provided with an indicator rather like the two hands of a clock, to be fixed in front of the chimney. The two hands or arms of the indicator can be set in any position, and by their particular angle indicate the route the train is to follow. In the picture on this page—of a West Coast Scotch express running between Glasgow and Carlisle—the route is indicated by setting the hands at "a quarter to three." But now that the Caledonian has become a part of the great London, Midland and Scottish

THE SMALLEST PASSENGER RAILWAY IN THE WORLD.
In Eskdale, Cumberland.

system, this special code will be gradually abandoned in favour of the " national " code of headlights.

Another matter that I might mention is the carrying of numbers on the front of engines. These usually indicate that the train concerned is a " special " train—that is to say, one that is not shown in the ordinary time-tables. In such cases, the train is given a number in the " weekly working notice," which tells the staffs of all the special arrangements for the week, and the engine carries a corresponding number, so that the train may be easily recognised by all the people concerned. The South Western section of the Southern Railway, however, now makes every engine carry the " number " of its train, as you can see in the photograph at the head of the chapter.

A Heavy Great Eastern Coal Train, L. & N.E.R.

The three white discs above the buffers indicate a " through mineral " train ; the green disc at the foot of the chimney shows it is a " special " working.

New Standard Sleeping Car, London, Midland & Scottish Railway

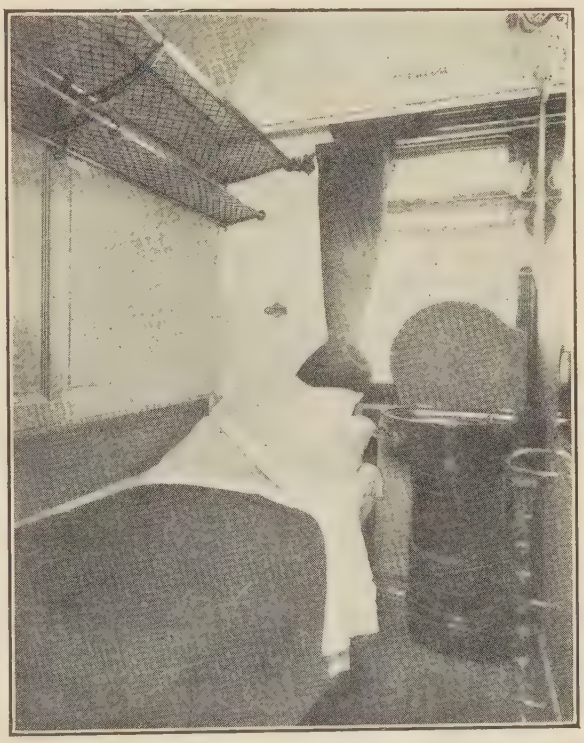
SLEEPING WHILE YOU TRAVEL

IT is only a small proportion of the journeys in this country that are long enough to make sleeping cars worth while. In fact, sleeping cars are only run between London and Scotland, as well as to the northern English cities, and then westwards to South Wales and the distant places of Devon and Cornwall. Business men in particular value a sleeping car, because it enables them to do a day's business, say, in London, then to go to bed in the train, and to wake up the next morning in Glasgow, for example, ready to do business up there, without having wasted a day on travelling.

Nothing could be more comfortable than one of our present-day " sleepers," such as the East Coast coach of which you see the inside opposite. It is divided into ten or eleven separate " bedrooms," each of them opening out on to the corridor. Space, of course, is very precious ; and after all the beds have been arranged crossways there is just about enough space left in each bedroom to turn round. Even then this coach, with its ten or eleven rooms, holding only the same number of people, weighs 45 tons or so, which readily explains why such heavy prices have to be charged for the use of a " berth."

Everything inside the compartments is beautifully fitted and arranged ; hot and cold water is laid on in each one ; electric lights that can be turned up full or burned with a dim light ; electric fans ; and hosts of other aids to comfort. At the end of the sleeping car is a compartment for an attendant, who looks after the wants of the occupants, and can supply them with tea and coffee and other light refreshments. Then every device making for smooth running and the deadening of noise has been used in building the car, very special attention being paid to the springs, and to interposing layers of rubber between the steel " frame " and the timber " body."

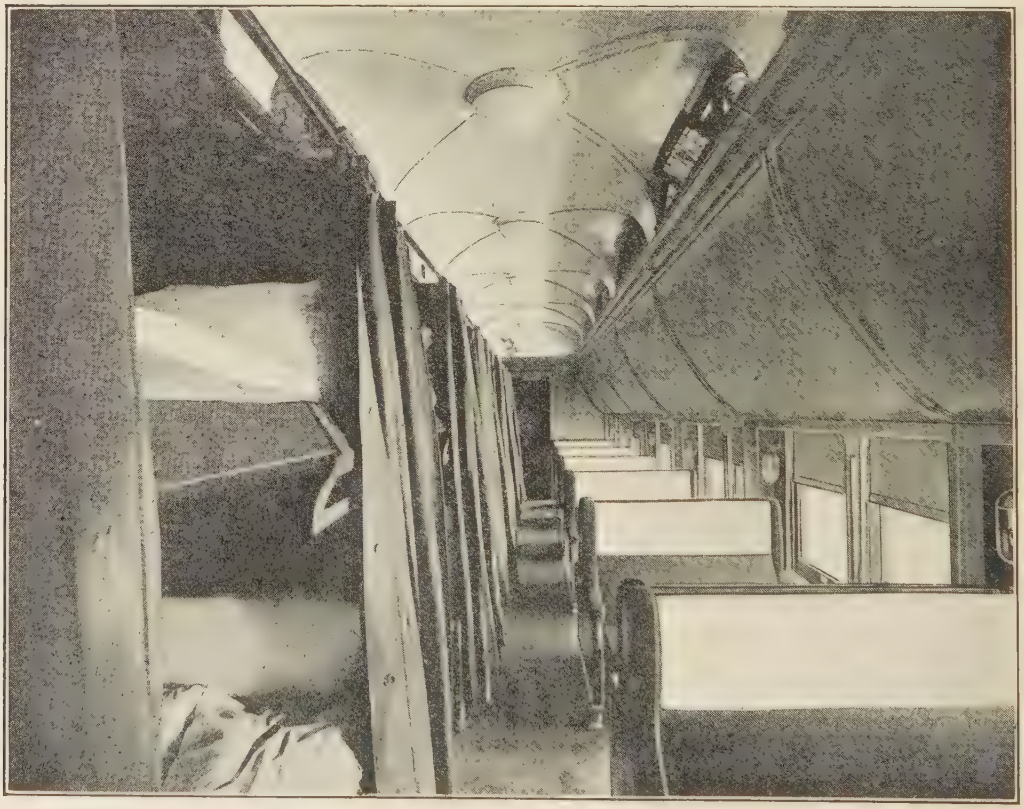
In other countries, where journeys have to be made which often mean living in the train for days together, sleeping accommodation has to be provided on a larger scale. Continental sleeping cars generally have two berths in each room, one above the other, which, of course, doubles the capacity of the car. On other railways, such as the well-known " P.L.M." of France, running from Paris down to the Riviera, besides the special sleeping-car trains, trains are run in which the ordinary compartments can be made into bedrooms at night by pulling out the seats till they meet in the middle, and turning them into beds.



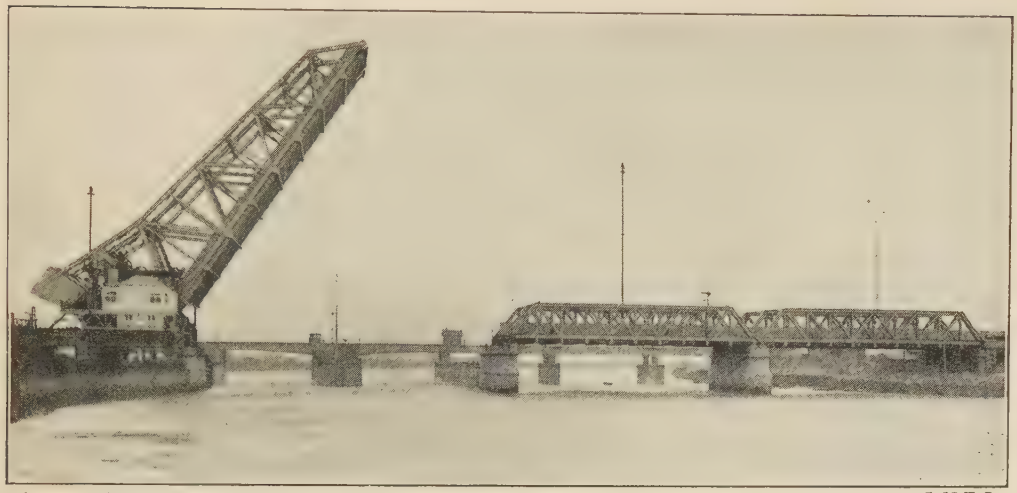
A Sleeping Berth on the Night " Scotsman," London & North Eastern Railway

In Canada and America,

where a journey across the continent may take a full week, it is quite customary to build big cars which are used as ordinary coaches in the daytime, and turned into sleeping cars at night. This picture of a Canadian Pacific Railway sleeping car shows the arrangement very clearly. On the right-hand side you see how the coach is arranged for day use ; and then, on the left-hand side, part of the roof has been let down to form a series of upper berths, and the seats have been pulled out to make the lower berths. You have to undress and get into bed behind the curtains. This is neither so comfortable nor so private as our English type of sleeping car, but it has the advantage of providing a bed at night-time for everybody on the train.



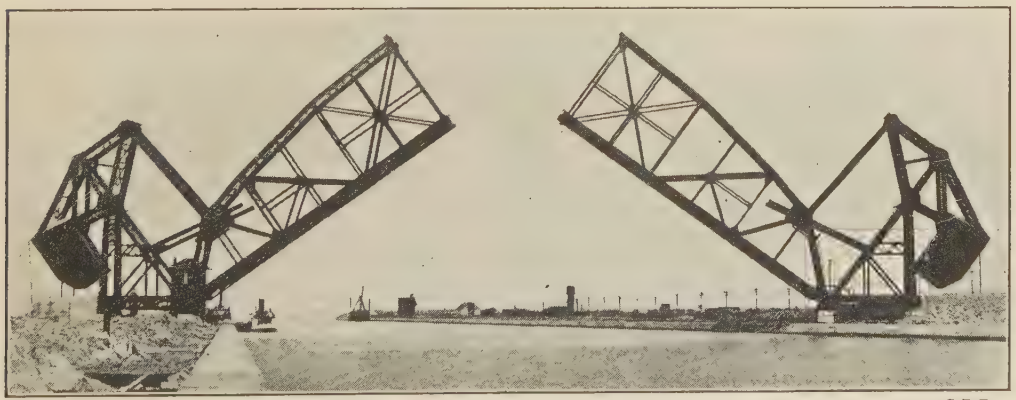
INTERIOR OF STANDARD " SLEEPER," CANADIAN PACIFIC RAILWAY
On the right are the seats as arranged for day use, and on the left the berths have been made up ready for the night.



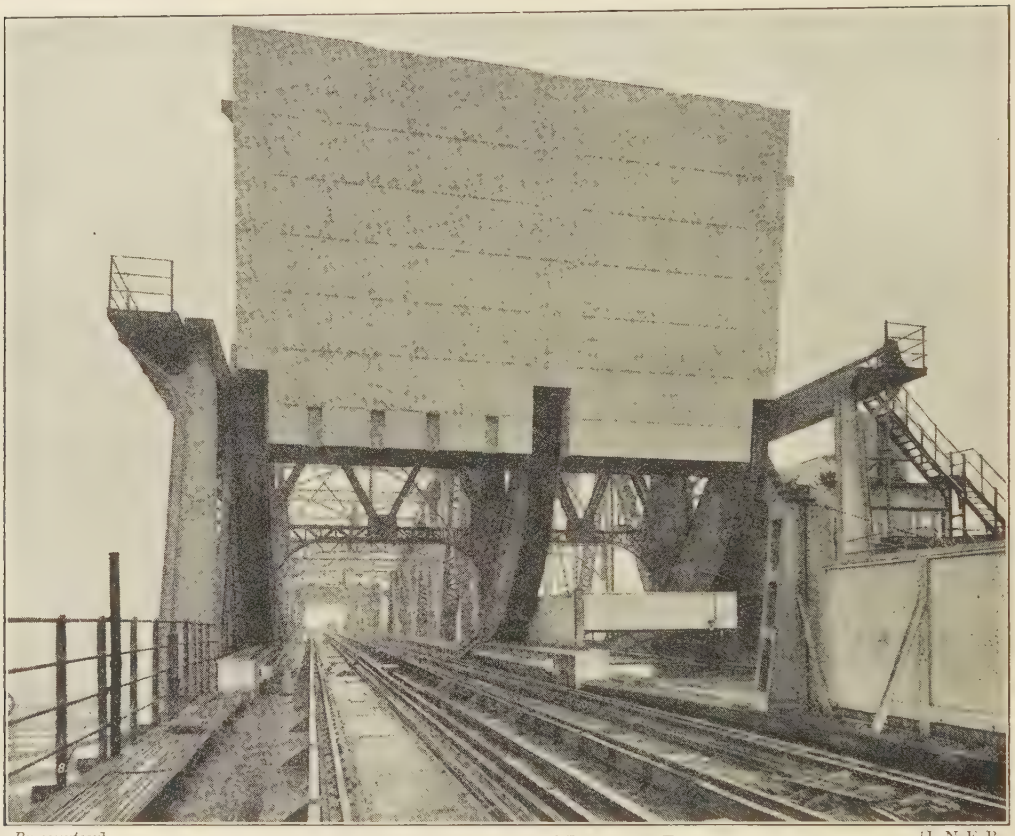
By courtesy] KEADBY BRIDGE OVER THE RIVER TRENT [L.N.E.R.

RAILWAY BRIDGES THAT OPEN

WHEN a railway crosses a river or a canal up which steamers pass, special arrangements must be made in order that the masts and funnels of the boats shall not be obstructed by the railway bridge. In some cases, like those of the Forth Bridge, the railway itself has been raised sufficiently high to clear the biggest boats that are likely to pass underneath. In other cases, where the interruption of railway traffic does not matter quite so much, a bridge



By courtesy] BASCULE BRIDGE AT SAULT STE. MARIE, CANADA [C.P.R.



By courtesy] THE BALANCE-WEIGHT, KEADBY BRIDGE [L.N.E.R.

is designed which can be opened, when required, to give a clear water passage.

Two kinds of opening bridges may be seen in the picture at the head of this chapter, which shows the busy North Lincolnshire line of the L.N.E.R. crossing the wide estuary of the River Trent at Keadby, between Doncaster and Grimsby. In the background is the old " swing-bridge," which has now been abandoned and broken up ; in the foreground is the new " rolling lift " bridge. The opening span of the former swings round about its centre, so making two water passages, one on each side of the centre tower ; but the rolling lift bridge, when open, stands right up on end, as you can see, making a water channel twice as wide as the old bridge.

The principle of the rolling lift bridge is clear in the photograph opposite, which shows the roller-gear on which the bridge moves, and the enormous steel balance-weight that balances the weight of the lifting span, so enabling the latter to be lifted easily. The bridge is shown open to the railway—and also to the main road that runs alongside—and closed to the river. Needless to say, very careful signalling arrangements have to be made to prevent trains from running on to the bridge when it is open to the river.

Of the two Canadian bridges illustrated, that at Sault Ste. Marie, on the Canadian Pacific Railway, is a " bascule " bridge, in which two lifting spans are employed, just like the Tower Bridge in London. The bridge of the Canadian National Railways at Prince George is arranged so that the whole of the short span in the foreground is lifted into the air when the bridge is open to the river, instead of being hinged at one end.

By courtesy] [C.N.R.

OPENING BRIDGE AT PRINCE GEORGE, BRITISH COLUMBIA

Photo [F. E. Mackay

THE "SOUTHERN BELLE," SOUTHERN RAILWAY

WORLD-FAMOUS EXPRESS TRAINS

ONE of the most famous of our British trains is the "Flying Scotsman," which leaves King's Cross terminus in London every morning at ten o'clock for Edinburgh, Glasgow, Perth and Aberdeen. Since 1862 it has left at exactly the same time, which in itself is a record. Less than thirty years ago there were no corridor carriages or dining cars, and a halt of twenty minutes was made at York while passengers bolted a very hasty lunch. To-day passengers enjoy every luxury that it is possible to provide in two magnificent trains which were put into service in 1924; meals and refreshments are obtainable throughout the journey, and all the cooking is done by electricity.

Because it hugs the East Coast for a great part of the distance, the route followed by the "Flying Scotsman" is known as the "East Coast Route." On the other side of the country the main line of the London, Midland and Scottish Railway to Scotland is known as the "West Coast Route," and a West Coast day Scotch express is seen in another coloured illustration, passing Tebay at full speed. Tebay is situated in the wilds of the Westmorland hills,

Photo] [F. E. Mackay

ONE OF THE HEAVIEST EXPRESS TRAINS IN BRITAIN
LEEDS AND BRADFORD EXPRESS, L.N.E.R.

and is just at the foot of the steep incline leading to Shap Summit, 915 feet above sea-level. When the express trains are very heavy, it is necessary for them to stop at Tebay, in order that they may get the assistance of a " banking engine," which will help them in their climb to the summit by giving a friendly push behind.

Photo] [F. E. Mackay

ONE OF THE FASTEST TRAINS IN BRITAIN
CHELTENHAM TO PADDINGTON EXPRESS, G.W.R.

Photo] [Loco. Publishing Co.

THE LONGEST NON-STOP RUN IN THE WORLD
"CORNISH RIVIERA" EXPRESS NEARING EXETER, G.W.R.

The Great Western Railway holds most of the records for speed in this country. The 3.45 p.m. train in the afternoon from Swindon to Paddington is allowed only 75 minutes in which to cover a distance of $77\frac{1}{4}$ miles, and the 7.10 p.m. from Paddington to Birmingham, also, is booked to run from Princes Risborough to Leamington, a distance of 53 miles, in 51 minutes. Both these trains have therefore to keep up an average speed of well over 60 miles an hour, and when due allowance has been made for getting up speed, and slowing down again, it means that many miles must be covered at over 70 miles an hour, if time is to be kept. Credit for the highest speed ever recorded in this country behind a locomotive also belongs to the Great Western Railway, which in racing the Transatlantic mails

from Plymouth to London in 1904, attained 102½ miles an hour down a gradient near Taunton, and kept up a speed of round about 80 miles an hour all the way from Swindon to Paddington.

When it comes to long runs without a stop, the Great Western Railway again heads the list. The famous " Cornish Riviera Limited " express, leaving Paddington at half-past ten in the morning, does not stop anywhere short of Plymouth, 226 miles away from London ; although it does, without stopping, set down passengers by slip coaches at Westbury, Taunton and Exeter. This is the longest non-stop run in the whole world, by a wide margin. In the summer the Great Western does the 200 miles between Paddington and Torquay in both directions without stopping, and all the year round there are expresses which run the 174 miles between London and Exeter, both ways non-stop, in the fast time of three hours, averaging 58 miles an hour.

The London, Midland and Scottish Railway is also responsible for some lengthy non-stopping runs. The evening " diner," leaving

Photo] [F. E. Mackay

AMONG THE WESTMORLAND FELLS
WEST COAST SCOTCH EXPRESS NEAR TEBAY, L.M.S.R.

Photo] [J. M. Robbins

BELFAST TO DUBLIN EXPRESS
GREAT NORTHERN RAILWAY OF IRELAND

Euston at 5.55 p.m., does not halt until it reaches Edge Hill Station at Liverpool—a distance of 192 miles. On the London and North Eastern Railway the all-the-year-round non-stop record is held by the famous "Harrogate Pullman," which bridges the 186 miles between King's Cross and Leeds, down and up, without any halt on the way intermediately. Some very fast running is also performed over certain portions of the London and North Eastern system, especially along the magnificent racing stretch—both straight and level—from Darlington to York. For many years past an express has been booked to cover the distance of a little over 44 miles in 43 minutes, start-to-stop, and until the institution of the Great Western 75-minute run from Swindon to Paddington this was the fastest daily journey in the British Empire.

On the Great Central section of the same railway, again, there are such timings as 65 minutes for a little over 65 miles from Aylesbury to Leicester; and then the down newspaper express, leaving Marylebone in the small hours of the morning, makes three striking "sprints" in succession—from Brackley to Rugby, 24 miles in 24 minutes; Rugby to Leicester, 20 miles in 20 minutes; and Leicester to Arkwright Street Station at Nottingham, 22½ miles in 22 minutes. When you realise that each of these is a run from dead start to dead stop, over a sharply undulating road, and that time is lost both in getting up speed from each start and in slowing down again, you will understand why a whole string of eighty-miles-an-hour

maximum speeds is necessary if the precious papers are to arrive on time, as they invariably do.

The most famous train on the Southern Railway is probably the luxurious " Southern Belle " express, composed entirely of Pullman cars, which every day makes four journeys of 51 miles between Victoria and Brighton, each in the even hour.

Before the war, the Northern Railway of France had the reputation of running the fastest trains in Europe, and even now it runs the fastest British services very close. The midday boat express from Paris to Calais is only allowed 195 minutes to run the 186 miles, and this includes a stop of 4 minutes at Abbeville for water (because there are no track-troughs), and also a tremendous climb from the outskirts of Boulogne up to the summit at Caffiers, which brings down the speed considerably. In pre-war days, too, the morning express for Berlin, leaving Paris at 7.50 a.m., used to be booked to cover the 96 miles out to St. Quentin in 93 minutes, and was the fastest train in Europe. But, as slow running is still necessary through parts of the war-devastated area of France,

Bombay to Poona Express, Great Indian Peninsula Railway

Photo] [W. H. C. Kelland

ENGLISH BOAT EXPRESS, NORTHERN RAILWAY OF FRANCE

which are traversed by this express, the old time is not yet quite restored.

Most of the best and fastest trains on the Continent are called "Trains de Luxe," and consist of dining and sleeping cars only. Some of them run for several days and nights at a stretch, such as the Orient Express, which travels right across Europe from Calais to Constantinople. Another of these trains—the Côte d'Azur Rapide—runs from Calais down to the Riviera, and from the use of magnificent new sleeping cars (built, by the way, in England), painted royal blue, has come to be christened the "Blue Train."

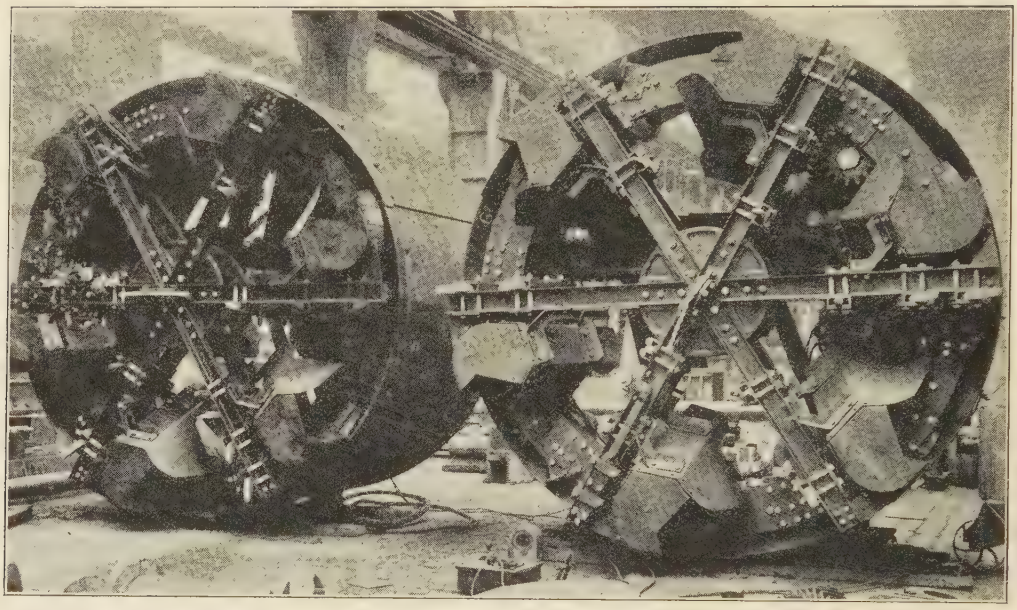
America used to hold the "blue riband" for railway speed. It was possible before the war for business men to make their morning and evening journeys between the city of Philadelphia and the popular seaside resort of Atlantic City in the even hour. But as this involved crossing in a ferry a wide river at the Philadelphia end,

for which ten minutes were necessary, it left to the locomotives of the Philadelphia and Reading Railroad the task of covering the remaining $55\frac{1}{2}$ miles of the journey in 50 minutes, start-to-stop. On one occasion the journey was actually completed in 43 minutes. But the loads of the expresses are so much heavier to-day, that it has been found necessary to extend the fastest time to 55 minutes.

American railway speeds in general are not so high as our speeds over here. But the Americans have some remarkable long-distance trains, nearly all of which carry fancy names. There is, for example, the " Twentieth Century Limited " of the New York Central Lines, and the " Broadway Limited " of the Pennsylvania, both linking the great cities of New York and Chicago. Other names, which abound in hundreds, such as " Buckeye Limited," " Katy Flier," " New Yorker," " Wolverine," and so on, sound strange to us, but are used universally in the United States. The chief of these expresses are hotels on wheels, equipped with sleeping, dining and drawing-room cars, libraries, wireless, and even a barber !

Photo] [Loco. Publishing Co.

AN AMERICAN TRANSCONTINENTAL EXPRESS



ROTARY EXCAVATORS USED IN PRESENT-DAY TUNNELLING

TUNNELS

(Photos by courtesy of London Underground Railways, except as otherwise noted)

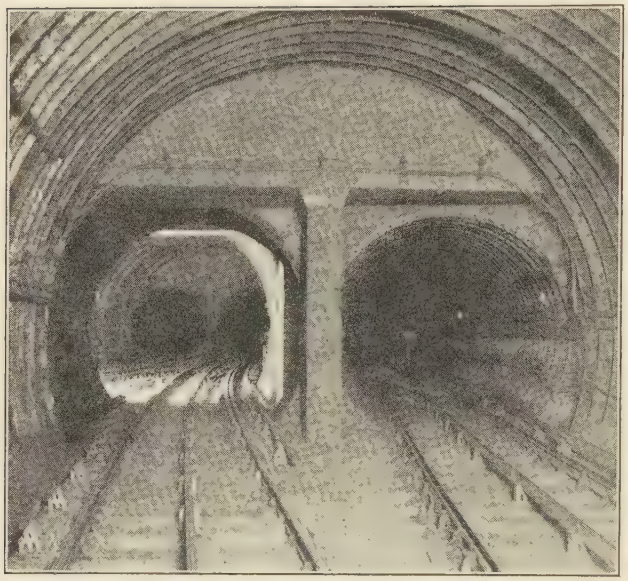
THE two formidable appliances, seen in the picture at the head of this chapter, are a reminder of the heavy cost of boring railway tunnels. They are known as Price Rotary Excavators, and have greatly speeded up the work of boring our tubes. Each of the six big spokes, like those of a wheel, carries " teeth," and the whole of the wheel is arranged to rotate inside its circular shield, which is like the barrel of a drum. Not only so, but there is also gearing inside the drum which drives the wheel slowly forwards. As it advances, the cutting teeth gradually slice away the earth in front of them, and deliver it into chutes which pass it to the back of the excavator, and from there it is loaded into wagons to be run away out of the tunnel. With this remarkable tool it is possible to drive the tunnels forward from twenty to twenty-five feet a day.

This excavator was a development of the Greathead Shield, in

the next picture, which also represented a great advance on the previous methods of boring tunnels. The shield encases just one big circular cutting edge, which is driven very slowly forward by hydraulic rams, while the material inside is shovelled away into wagons by the navvies. The tunnel itself is then actually built up inside the shield—just like two lengths of a telescope—and the narrow space that has been left between the tunnel and the outside of the drum is filled in with cement, which is run in under pressure by the process known as "grouting," and sets solid. Tube tunnels are not built of brick or stone, but "segments" of cast iron are used, about an inch in thickness, and fitting together in such a way as to make the complete circle of the tube.

The most remarkable of all our tube lay-outs is probably the recently-completed junction at Camden Town, which figures in the next pictures, on page 78. Originally, the Charing Cross, Euston

Inside a Greathead Tunnelling Shield



THE TUBE JUNCTIONS AT CAMDEN TOWN

(which have themselves been extended to Edgware) and the Highgate tubes. The extraordinary complication of tunnelling that this has involved is very clear in this diagram; it is in order that no two trains in any direction shall have to cross each other's paths on the level.

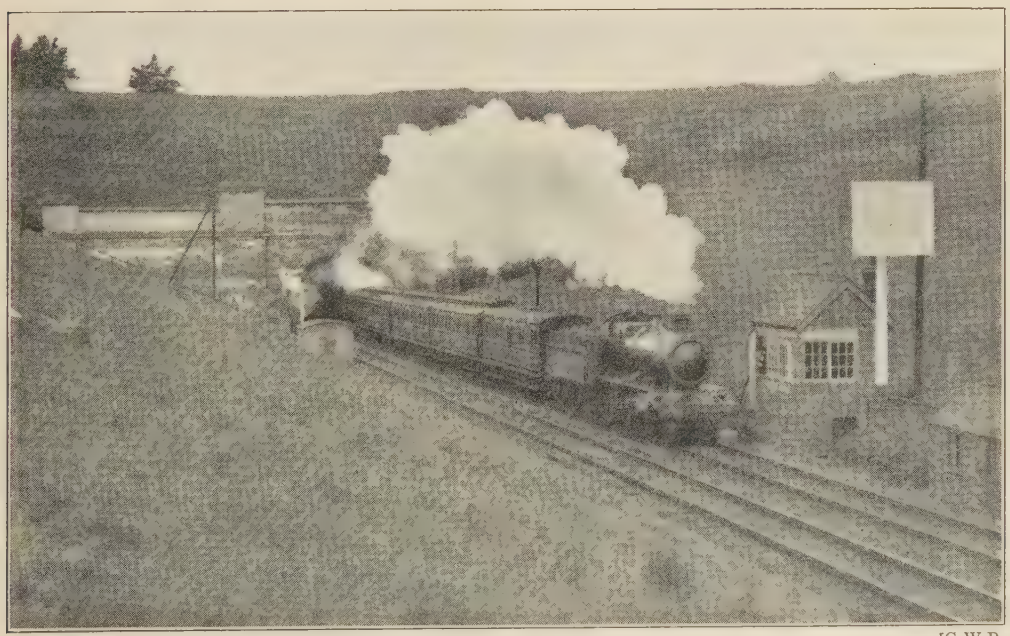
The dotted lines and the little arrows on the diagram show how ingeniously the junctions have been planned. In the photograph above you can just see, on the extreme left-hand side, the tunnel from Charing Cross to Highgate; the tunnel next to it is bringing the line from Moorgate, and the cross-

and Hampstead tube came up in the two tunnels at the bottom left-hand side of the diagram, and branched into two directions, the top left-hand tubes going off to Golder's Green, and the top right-hand ones to Highgate. Now the City and South London tubes have been extended from Euston to join up with both the Golder's Green tubes

A DIAGRAM OF THE TUBE LAY-OUT AT CAMDEN TOWN

over going away to the left carries the trains from Moorgate to Highgate ; then in the foreground you have the line from Moorgate to Edgware, on the left, joining that from Charing Cross to Edgware, on the right, Edgware being behind you. With this remarkable planning it is possible to run 40 trains per hour from each branch, or no less than 160 trains all over the junction in a single hour.

In not all of our tunnels has so simple a material as ordinary soil to be dealt with in the boring. In the North of England the mountain range of the Pennines cuts the country in two, from north to south, and every main line from east to west has to get through, in almost every case by tunnelling. But here it has been necessary to deal with rock, and this means blasting instead of excavation. The late North Western line cuts through, on its way from Leeds to Manchester, by means of Standedge Tunnel—three parallel bores, each just over 3 miles long ; the Great Central line from Sheffield to Manchester follows the two parallel bores of Woodhead Tunnel, also



By courtesy] SOUTH WALES EXPRESS LEAVING THE SEVERN TUNNEL [G.W.R.

3 miles in length; the Midland Sheffield and Manchester line threads three long tunnels—Totley, $3\frac{1}{4}$ miles; Cowburn, just over 2 miles; and Disley, $2\frac{3}{8}$ miles.

The longest of our British main line tunnels is that by which the South Wales main line of the Great Western is carried under the estuary of the Severn, this being nearly $4\frac{1}{2}$ miles in length. Enormous difficulties were encountered in its construction, water breaking into the workings more than once, so that the ultimate cost was some two millions sterling of money.

In such countries as Switzerland, of course, there are far longer tunnels, under the vast mountain masses of the Alps. The St. Gotthard, the Mt. Cenis, and the Loetschberg Tunnels, are all from 8 to 9 miles long; but they are completely outstripped by the Simplon, whose two parallel bores, through the solid rock under the Simplon Pass, are no less than $12\frac{1}{4}$ miles long, and are the longest railway tunnels in the world. Three millions of money were needed to complete this vital link between Switzerland and Italy, and eight years were occupied in its construction.

By courtesy] THE ENTRANCE TO THE GREAT SIMPLON TUNNEL [Swiss Federal Rlys.

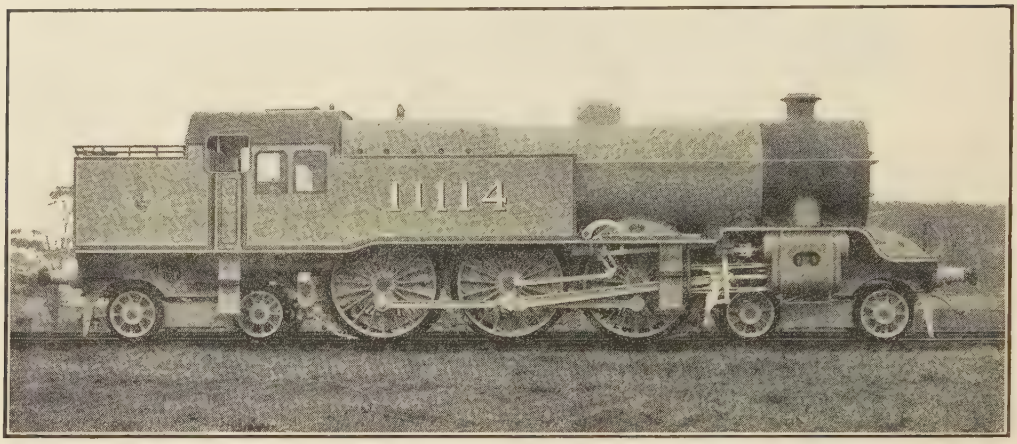
4-6-2 ("Pacific" Type) Express Engine, "Flying Scotsman," London and North Eastern Railway

LOCOMOTIVES AND THEIR WORK

EVEN in these days of electric locomotives, of motor-cars and of aeroplanes, nothing in connection with travel is quite so fascinating as the steam locomotive. There is something peculiarly human about the locomotive, indeed, which is not shared by any other piece of machinery.

First, we can divide locomotives up into two main classes—those with tenders and those without. The former carry their supplies of coal and water in a separate vehicle, or tender, coupled to the engine; in the latter, called "tank engines," the food and drink are carried by the engine itself, and a tender is dispensed with.

It is simply a question of length of journey. Main line engines have to travel long distances without replenishing their supply of coal, although, as we have seen already, water can be picked up from time to time without stopping by means of the track-troughs. The big eight-wheeled tenders of the London and North Eastern "Pacific" engines, one of which appears at the head of this chapter, hold no less than 8 tons of coal—enough to run the 376 miles from

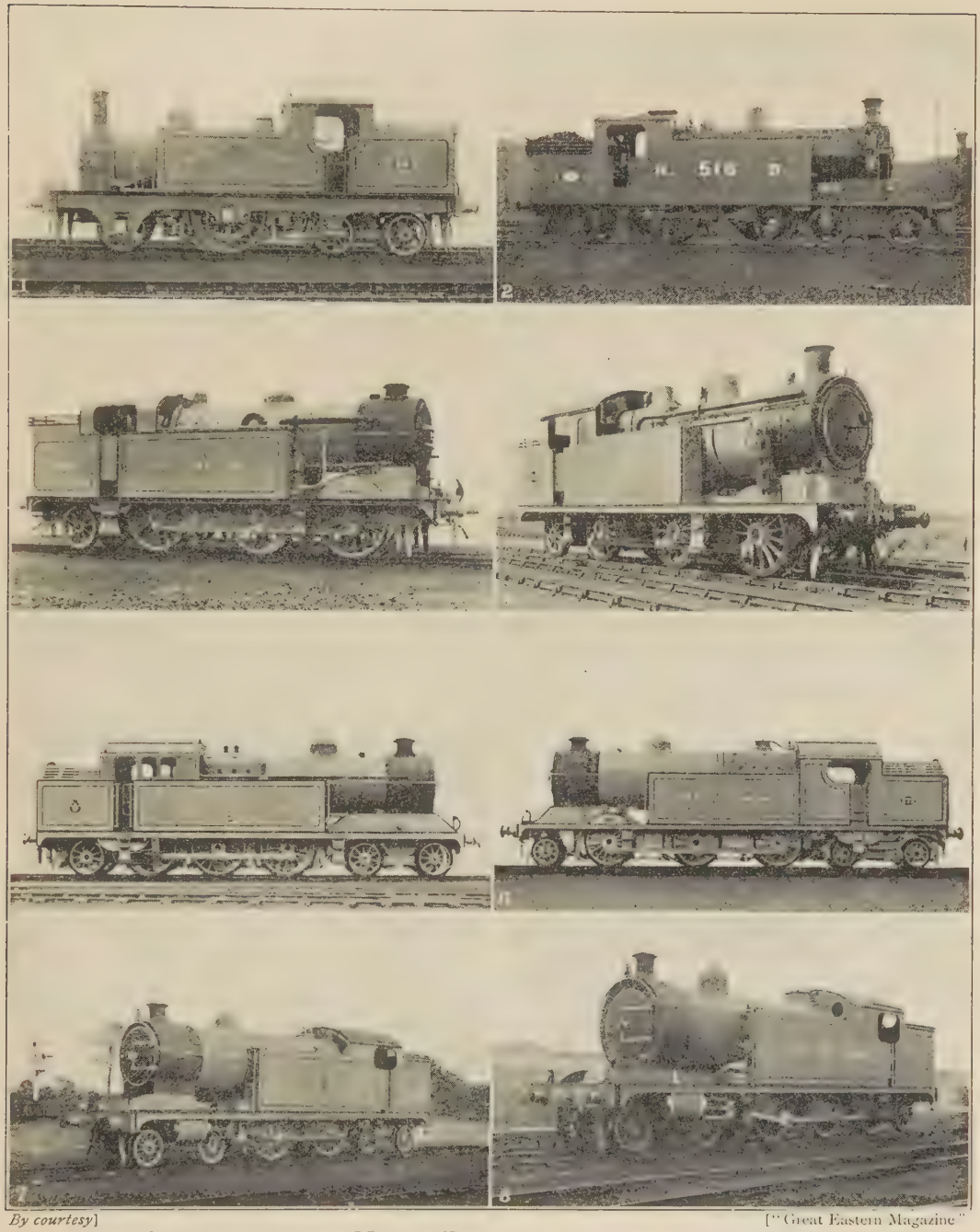


4-6-4 ("Baltic" Type) Express Tank Engine, L.M.S. Railway

London to York and back—when they are full ; while the tender of the enormous Canadian National engine on page 90 can accommodate 17 tons, as these engines make continuous runs of 333 miles from Montreal to Toronto without being changed. The tender in this case is carried on twelve wheels.

The principal part of the tender space, however, is occupied by the water tank, and a modern British tender will hold up to four or five thousand gallons of water. The Canadian tender I have just referred to holds ten thousand gallons ; but there are no track-troughs on the Canadian railways, and in addition this is a much bigger and more powerful engine than anything we should have room to build on the railways of this country.

But tank engines are intended for short journeys, where such large quantities of coal and water are quite unnecessary. So, in the majority of tank engines, water is carried in those large flat-sided tanks that you see along both sides of the boiler, and which give a tank engine so characteristic an appearance ; these tanks can hold a couple of thousand gallons or so. Coal is carried in the bunker at the rear end of the engine, which will take from 2 to 4 tons. Sometimes, in the case of shunting engines, the water tank is perched



By courtesy] ["Great Eastern Magazine"

SOME LONDON & NORTH EASTERN RAILWAY TANK ENGINES

1. 2-2-4 N.E. Tank for Special Trains.
2. 4-4-2 Passenger Tank, N.B. Section.
3. 0-6-2 Suburban Tank, G.N. Section.
4. 0-6-2 Suburban Tank, G.E. Section.
5. 4-6-2 Suburban Tank, G.C. Section.
6. 2-6-4 G.C. Tank for Mineral Trains.
7. 4-4-4 Passenger Tank, N.E. Section.
8. 4-6-2 N.E. Tank for Mineral Trains.

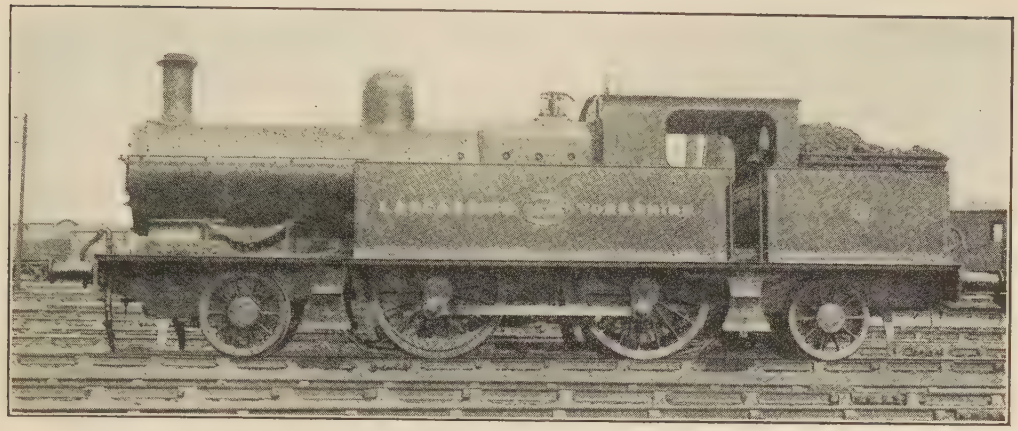
Photo] [F. E. Mackay

ONE OF THE BIG BRIGHTON 4-6-4 EXPRESS TANK ENGINES LEAVING VICTORIA, SOUTHERN RAILWAY

up on the top of the boiler, and the engine becomes a " saddle tank " instead of a " side tank." But side tank engines are much the more common.

The chief use of tank locomotives is on short-distance suburban train services, where it would be wasteful to haul about a great heavy tender all the time. Not only so, but for these short journeys an engine is needed which does not have to be turned round on a turntable at the end of each run. Any locomotive can run just as easily in a backwards direction, of course, as it can forwards ; but it is not advisable, in the case of a tender engine, for the engine to be pushing the tender in front of it when running at speed. Besides that, the look-out in front for the driver over a big tender piled high with coal is a very poor one. But the tank engine is specially designed with a good look-out both front and rear, and is

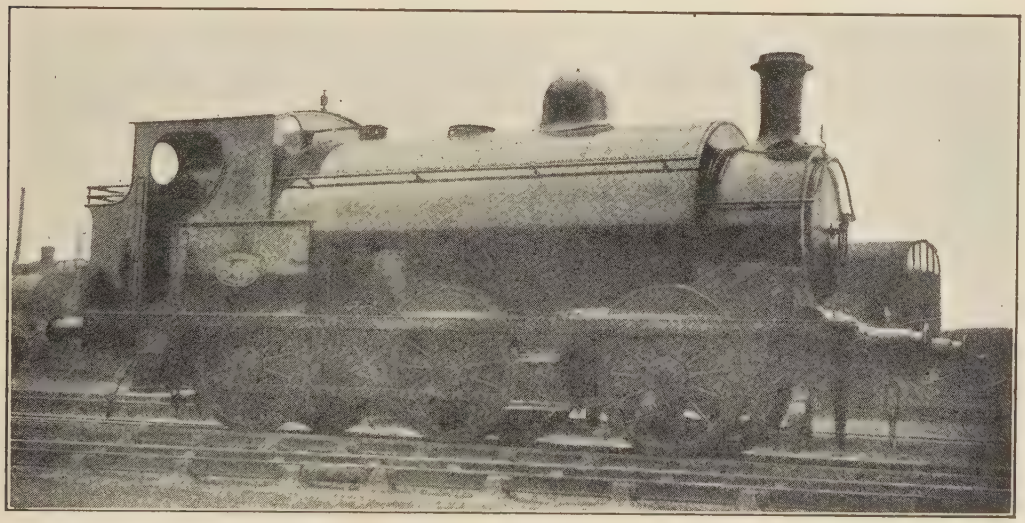
A 300-ton American "Mallet" Type Freight Engine.
Pennsylvania Railroad



A "Side" Tank Engine, L.M.S. Railway

the handiest of machines for running short-distance suburban trains, with quick turns round at both ends of the journey.

Of late years tank locomotives have come quite into favour for really fast express running over short distances. Here again there is no reason why great heavy tenders should be hauled about on such short runs, for example, as the 51 miles of the Southern Railway expresses between Victoria and Brighton. So for these services



A "Saddle" Tank Engine, L.M.S. Railway

very powerful " express tank " engines have been built by the Brighton line. These are really express engines in every respect other than having a separate tender ; and frequently touch such high speeds as 75 miles an hour and over when running to and from Brighton on the " Southern Belle " and other 60-minute trains.

The next thing that we have to notice is the size and arrangement of the wheels of the engine. This is a matter of no little importance ; it governs the work that the locomotive will be called upon to do when in service. Now, in order to understand this subject thoroughly, let us think of some particular type of engine : suppose we take the big London and North Eastern " Pacific " express engine that is illustrated at the top of the opposite page.

Leaving the tender out of account, you will notice that the engine is carried on wheels of different sizes. There are, if you look, three pairs of big wheels in the middle, pinned together by a long rod that goes flying round with them when the engine is in motion—the " business " wheels that do the real work of moving the engine and

Photo] [F. E. Mackay

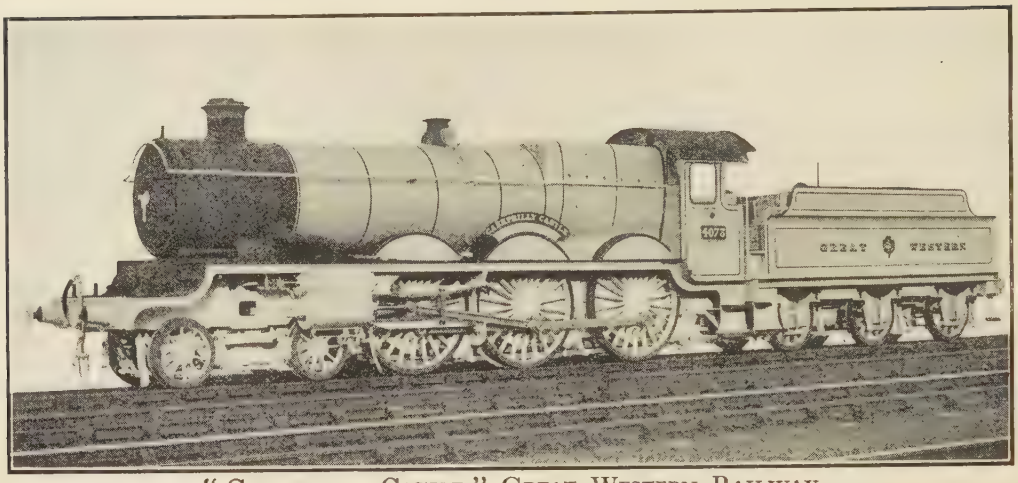
ONE OF THE OLD MIDLAND " SINGLE-DRIVERS " AT WORK

4-6-2 Type Express Engine, L. & N.E.R.

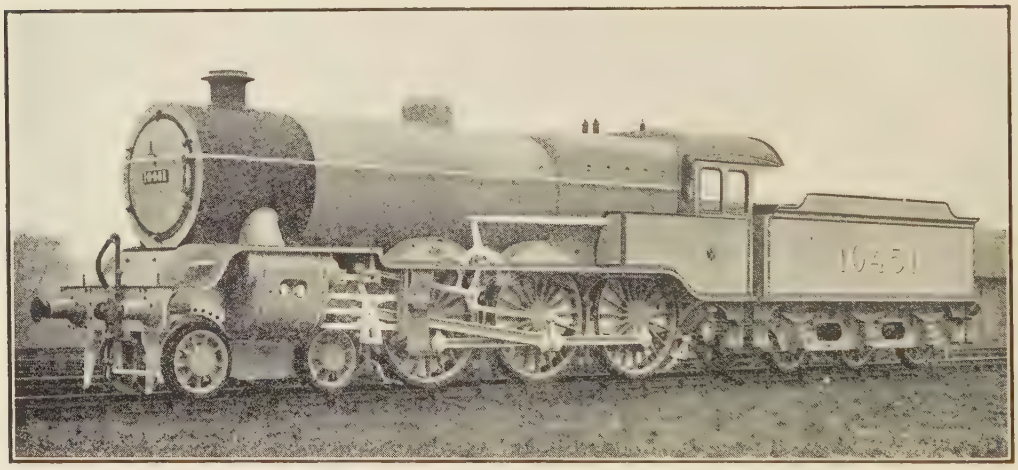
train. And then, in front of them and behind them, there are smaller wheels which we may call " idle " wheels, because their work is simply that of helping to carry the engine, and to distribute its great weight nicely and evenly over the track.

The two pairs of wheels in front are mounted on a small truck, called a " bogie " ; by means of a big pivot this carries the leading end of the engine, and enables it to swing smoothly and easily round the curves in the track, especially at high speeds. And the extra pair of wheels at the back end, under the driver's cab, allows the " firebox "—that vital part of the boiler that contains the engine fire—to be developed in size and improved in shape. When a pair of the big " driving " wheels comes right at the back of the engine, as it does in so many cases, the size of the firebox is restricted.

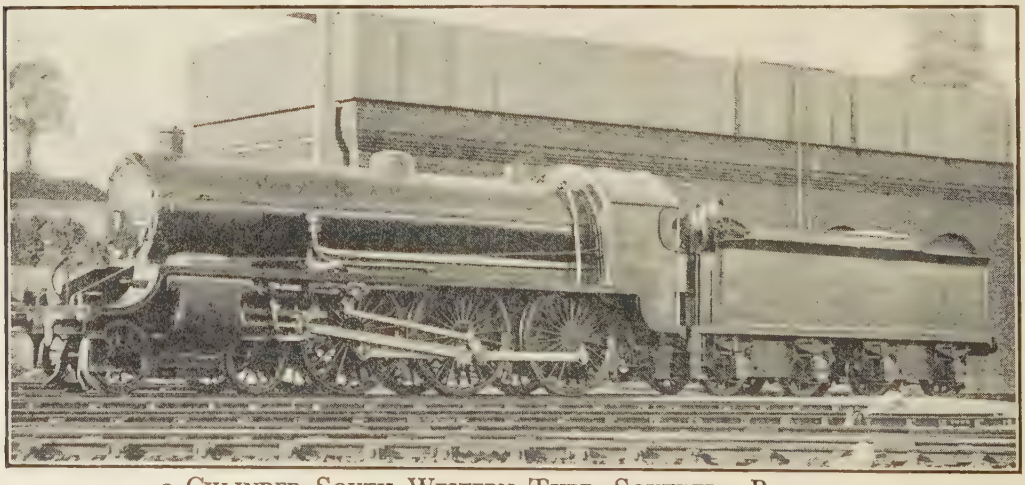
Now why is it necessary to have three pairs of driving wheels all coupled together ? The earliest express engines had one very large pair of driving wheels only, and so earned the name of " single-drivers." It is needful for you to realise, at this point, that the engine boiler might be able to raise very large quantities of steam, and the engine cylinders to develop enormous power ; but unless the driving wheels had sufficient grip on the rails, all the power developed would be valueless. The driving wheels would simply slip round on the rails and do no work.



"Caerphilly Castle," Great Western Railway



4-Cylinder Lancashire & Yorkshire Type, L.M.S. Railway



2-Cylinder South Western Type, Southern Railway

Some Present-Day 4-6-0 Express Engines

The amount of grip, or " adhesion," as it is called, depends on the weight that comes down upon the driving wheels, which, of course, bear their share of the weight of the engine. In fact, their share is really increased out of proportion, in order that as much of the weight of the engine as possible shall be available for increasing this grip. But then, on the other hand, a line must be drawn somewhere, or else you might bring so heavy a weight on one pair of wheels that the track and the bridges under the line would not stand it.

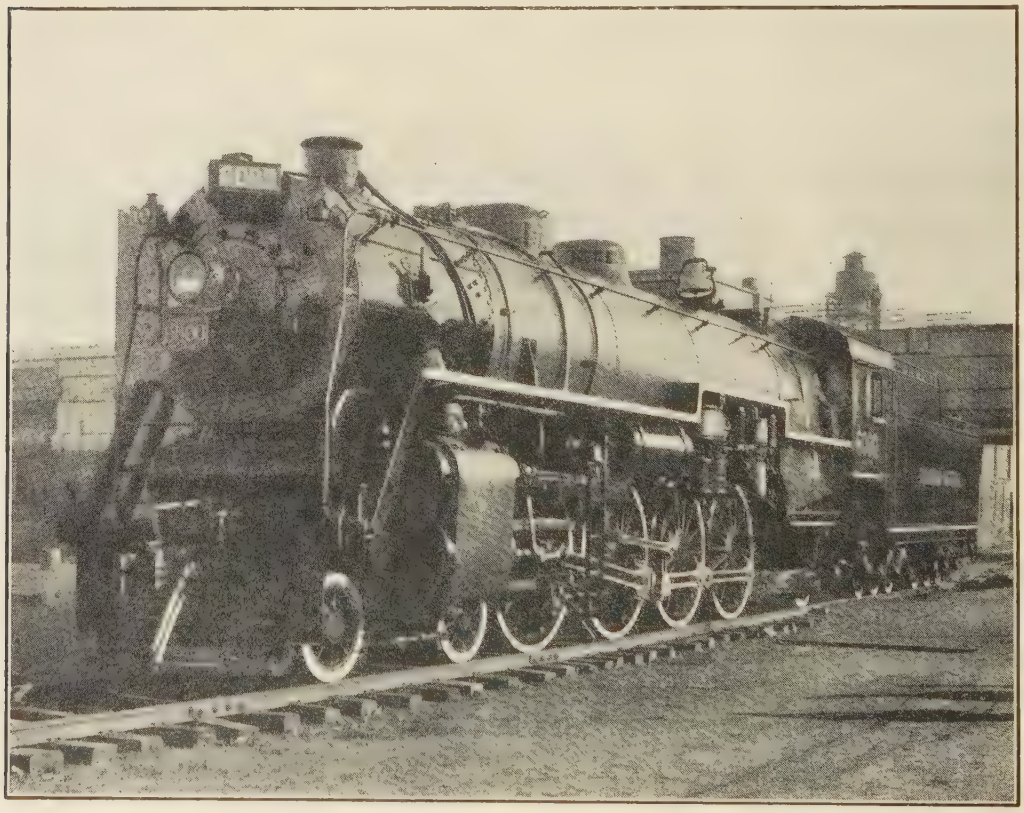
And so, as you can easily see, when trains grew gradually heavier —as they are doing all the time with the introduction of dining cars, and corridors, and more comfortable coaches, let alone the greater number of people travelling—the weight on one pair of driving wheels was no longer sufficient. Twenty tons on one pair of wheels is as much as we dare allow, although our American friends take rather greater risks, and go up to 30 tons on a pair of wheels. So what was done was simply to fit the engine with another pair of driving wheels of equal size, and to couple the two together with the " coupling-rods " that you see in all these pictures. This, in effect, made the two pairs of wheels act as one, and doubled the " adhesion weight " of the engine.

From the " four-wheels-coupled," or, for short, " four-coupled," engine we have gone on by degrees to six-coupled, eight-coupled and even ten-coupled engines, while there have been cases abroad where as many as six pairs of driving wheels have been coupled, making a twelve-coupled engine. For passenger work, four-coupled or six-coupled wheels are generally considered sufficient, as beyond that the coupling-rods begin to be a hindrance to high speed.

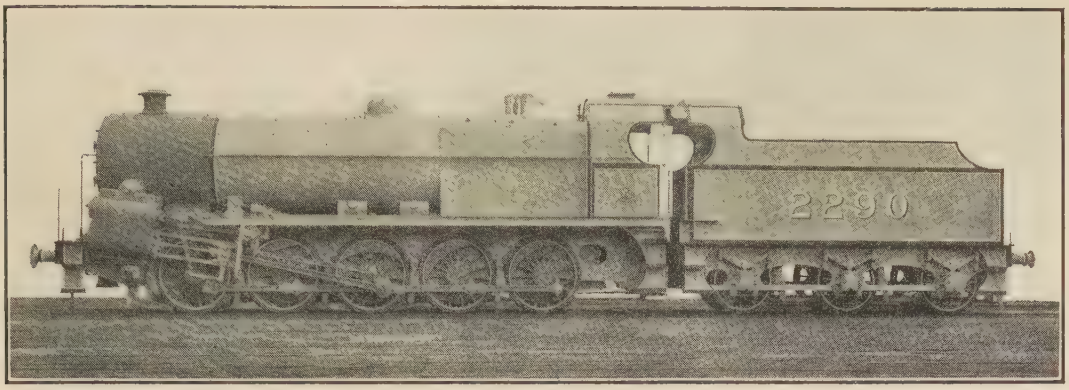
But in other countries, where heavy express trains have often to be worked over tremendously steep gradients, eight-coupled engines are quite often employed for passenger trains. The enormous Canadian National Railway engine illustrated on page 90 is a case

in point; this has to handle trains up to fifteen heavy all-steel coaches, weighing as much as 1000 tons, whereas in this country 400 to 500 tons, or a little over, is the outside weight for an express.

It is of interest to note here that the Canadian National engine, which is claimed to be the most powerful passenger locomotive in the world, weighs with its tender 259 tons in working order, as compared with the 150 tons of our heaviest engine—the London and North Eastern "Pacific." Out of the engine weight, 101 tons are available for "grip," against 60 tons in the English engine. But in Canada and America the railway builders have left some 3 feet more above their tracks than we have, and proportionate width too, which



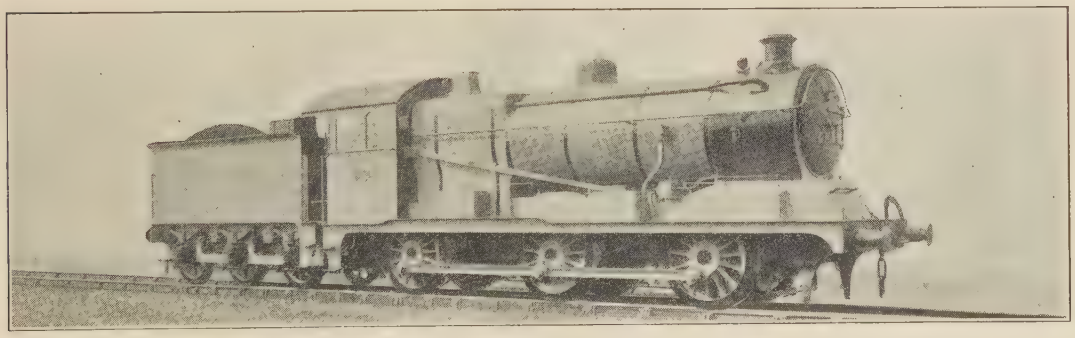
THE MOST POWERFUL PASSENGER ENGINE IN THE WORLD
NEW 4-8-2 ("MOUNTAIN" TYPE) LOCOMOTIVE, CANADIAN NATIONAL RAILWAYS



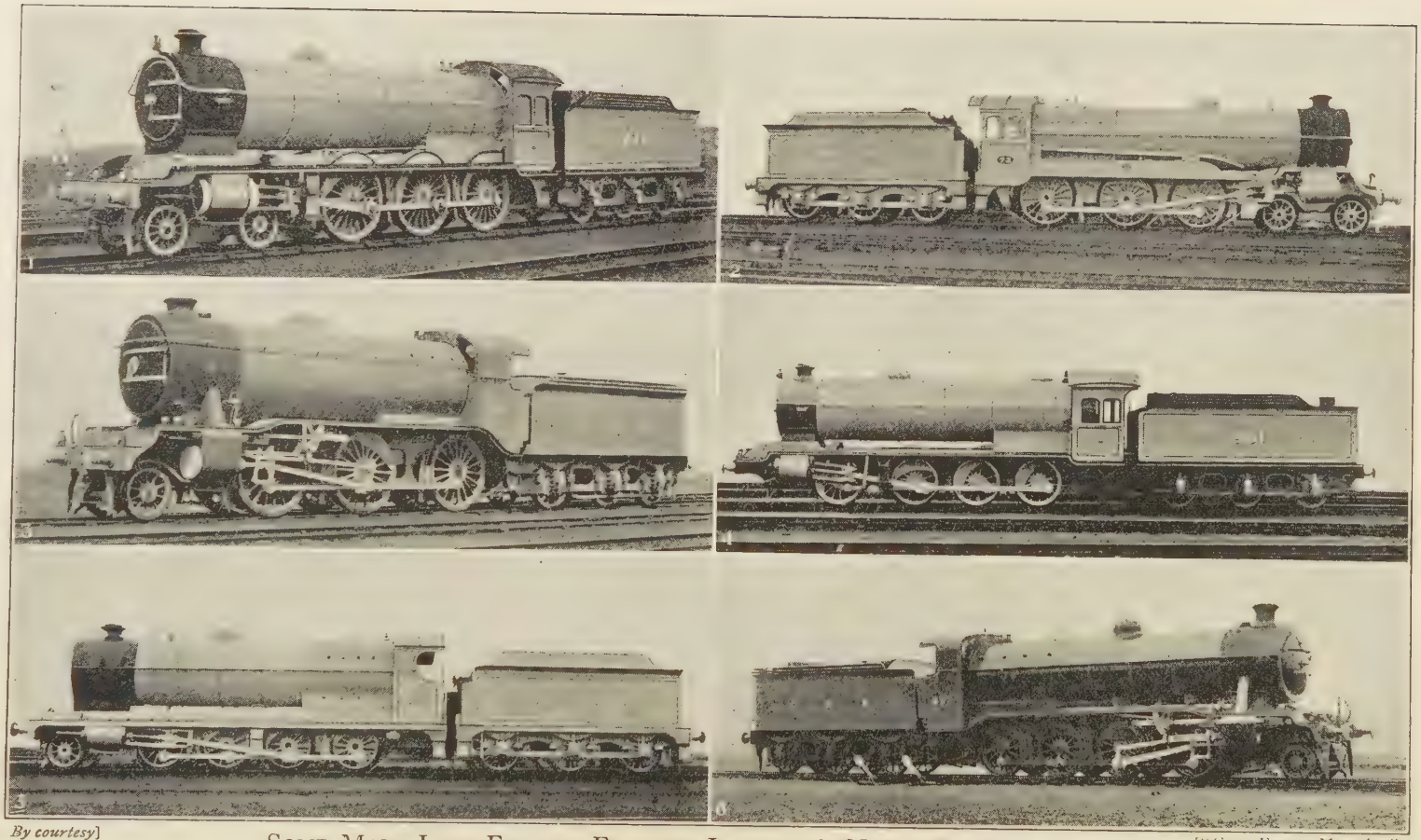
MIDLAND 0-10-0 ("DECAPOD" TYPE) BANKING ENGINE, L.M.S. RAILWAY

explains why they are able to build such enormous engines, although the gauge, or the distance between the rails, is just the same as in this country.

In the case of goods and mineral engines, which are not required to run at any great speed, no "bogie" is required, and very often no "idle" wheels are used at all, as with both the engines on this page. So all the wheels of such engines are driving wheels, and the whole of the engine weight is available for grip, or adhesion. Goods engines never have less than six wheels coupled, and very frequently eight-coupled wheels are used. There is only one ten-coupled engine in this country, and that is the tremendously powerful Midland engine used by the London, Midland and Scottish Railway for



0-6-0 TYPE GOODS ENGINE, GREAT EASTERN SECTION OF L. & N.E.R.



By courtesy] SOME MAIN LINE FREIGHT ENGINES, LONDON & NORTH EASTERN RAILWAY ["Great Eastern Magazine"

1. 3-cylinder 4-6-0 Express Goods Engine, N.E. Section.
2. 4-cylinder 4-6-0 Express Goods Engine, G.C. Section.
3. 3-cylinder " Mogul " Express Type, G.N. Section.
4. 3-cylinder 0-8-0 Mineral Engine, N.E. Section.
5. 2-cylinder " Consolidation " Mineral Engine, G.C. Section.
6. 3-cylinder " Consolidation " Mineral Engine, G.N. Section.

Inside a Restaurant Car Kitchen on the L.M.S. Railway

pushing West of England trains up the steep Lickey incline, from Bromsgrove to Blackwell, near Birmingham, shown on page 91.

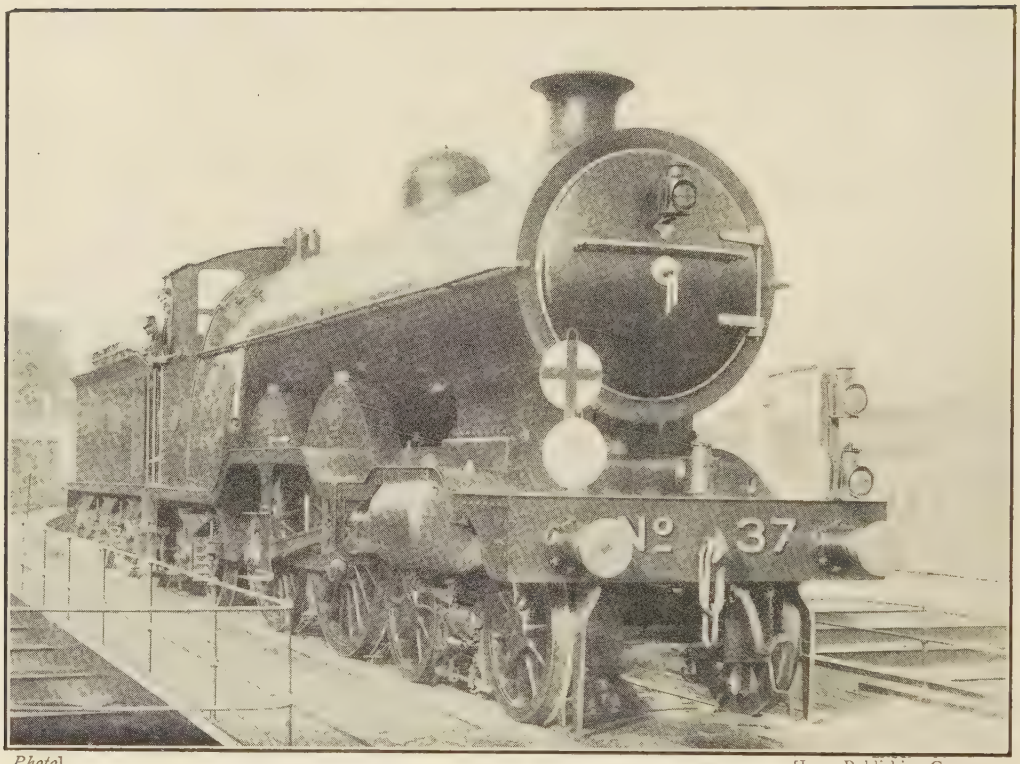
The work that the engine is designed to do also governs the size of the driving wheels. Big wheels mean higher speeds and less pulling power, generally speaking, and small wheels give power at the expense of speed. The old " single-drivers," like the Midland type (see page 86), had driving wheels between 7 feet 6 inches and 8 feet in diameter. Modern express engines have driving wheels usually about a foot less in diameter than this. Goods engines are content with 5-feet driving wheels, or thereabouts.

And now just a word as to how we describe engines by numbers. By the use of certain numbers, based on the arrangements of the wheels, we are able to describe an engine in such a way as to know what type it is, and, with fair accuracy, for what work it is intended. Let us take that London and North Eastern " Pacific " again as our example.

Starting from the chimney end, we see that there are four " idle," or carrying wheels in front ; so we write down the figure " 4." Then there follow the six big driving wheels, three on either side ; to indicate these we add a " 6." Last of all, there is the single pair of wheels under the rear end of the engine ; this gives us a final " 2." The engine is therefore of the " 4-6-2 " type. The tender is not reckoned.

The middle figure of the notation always indicates the driving wheels ; and the figures to left and right the idle wheels at the front and back of the engine respectively. If there are no carrying wheels at all at front or rear, we must write down the figure " 0 " to make this clear ; " 0-6-0," for example, indicates one of the commonest types of goods engine in this country, such as the one illustrated at the bottom of page 91.

Some very frequently used nicknames have become associated



Photo] [Loco Publishing Company

"ATLANTIC" EXPRESS ENGINE, SOUTHERN RAILWAY, BRIGHTON SECTION

with certain arrangements of wheels. Most of them have come over to us from America. For example, the first 4-4-2 express engines on record ran between Camden City at Philadelphia and the favourite seaside resort of Atlantic City; so they were dubbed "Atlantics," and the name has stuck to 4-4-2 engines ever since. Similarly the 4-6-2 arrangement of wheels is known as the "Pacific," and the 4-6-4 as the "Baltic."

The monstrous Canadian National engine, to which I have referred several times, is of the 4-8-2, or "Mountain" type. Then there are freight, or goods engines, of the "Mogul" (2-6-0) and "Consolidation" (2-8-0) classes; you will see very large numbers of both on the Great Western Railway. The "Moguls" are usually looked upon as half goods and half passenger engines, and have fair-

sized driving wheels, up to 5 feet 8 inches or so in diameter ; so they are used to work either express goods trains or passenger trains other than the fast expresses. The commonest British type for working goods trains is the familiar 0-6-0.

Of express passenger engines in this country there are hundreds and hundreds of the 4-4-0 type ; in fact, the express trains of the Midland and South Eastern and Chatham lines are worked by nothing else. Up the East Coast main lines of the London and North Eastern Railway you find many 4-4-2, or "Atlantic" express engines, and these are now giving place to the huge "Pacific," or 4-6-2 type, like the engine illustrated at the beginning of this chapter. On railways other than those I have mentioned it is the 4-6-0 type which is used for the fastest and heaviest express passenger trains.

Then, when we come to tank engines, we find a simply innumerable number of different kinds. For the short-distance suburban trains, 0-4-4, 2-4-2, 0-6-2 and 4-4-2 engines are all very popular,

Photo] [F. E. Mackay

CROMER EXPRESS, LONDON & NORTH EASTERN RAILWAY
4-4-0 ENGINE "PILOTING" 4-6-0 ENGINE

and there is an illustration of each one of these types on page 83. For longer-distance work, the 2-4-2 expands on the North Eastern to the 4-4-4, with a bogie at both ends of the engine ; and the 2-6-2 (known in America as the " Prairie " type), used so largely on the Great Western Railway, grows on the Brighton, and various sections of the L.M.S., to the vast 4-6-4, or " Baltic " type, some of the biggest examples of which weigh all but 100 tons in working trim.

Then there are various kinds of tank engine which spend their time in the humble work of shunting. Every railway has hundreds of the handy 0-6-0 type tanks ; and there are also diminutive 0-4-0 engines, on four wheels only, for some of the lighter work. Much of the heavier work of " sorting " trains in the big shunting yards, where long goods trains have to be pushed slowly over the " humps " described elsewhere, is undertaken by powerful tank locomotives of the 0-8-2, 2-8-0, 0-8-4 and 4-8-0 types, all, as you can see, with eight wheels coupled ; and there are also 4-6-2 and 2-6-4 tank engines on other railways for short-distance goods working.

Photo] [F. E. Mackay

CHELTENHAM EXPRESS, GREAT WESTERN RAILWAY
HAULED BY THE FAMOUS 4-6-2 ENGINE NO. 111, " THE GREAT BEAR "

MY RAILWAY BOOK

THE WONDERFUL RAILWAY ENGINEERING PROGRESS OF ONE HUNDRED YEARS, ILLUSTRATED AND DESCRIBED FOR CHILDREN

BY

CECIL J. ALLEN, A.M.Inst.T.

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PART II

CONTENTS

	PAGE
The Railway "Groups"	1
Safety on the Tubes	8
Where the "Iron Horse" is Stabled	12
Carrying the Mails	14
Turning Locomotives Round	17
Electric Railways	18
Goods Trains and Their Working	23
Locomotive Giants of Other Countries	27
How Passengers are Handled	30
Threading the Alps—The Wonderful Railways of Switzerland	33
Planning and Making a Railway	49
Signals and Signalling	56
Railway Accidents	63
How a Locomotive is Built	65
Wonderful Railway Bridges	81
How Engines are Tested	89
Trains that Go to Sea	92
Seeing the Scenery	95

The West Coast "Scotsman" at Full Speed near Tebay, L.M.S.R.
From photo by F. E. Mackay.

Photo] [F. E. Mackay

HOW THE GROUPING AFFECTS OUR EXPRESS TRAINS

A London and North Western Engine "piloting" a Midland Engine on a Manchester Express.

THE RAILWAY "GROUPS"

AT the beginning of the year 1923 there took place what was probably the most momentous development in the whole of British railway history. The whole of our railways, big and little, whose numbers ran into hundreds, were swallowed up into four great "groups." As a result, apart from the Metropolitan Railway and the various Underground Railways of London (which also form one group), there are now only four enormous railway systems in Great Britain, which have taken in all the remainder.

This is, of course, the origin of various strange names of railways which have only been heard of during the last couple of years. One of these is the London, Midland and Scottish, known more familiarly as the L.M.S.; another is the London and North Eastern, or the L.N.E.R.; and another is the Southern. Of the big railway groups only the Great Western Railway retains its old and honoured name.

Then, of course, there are one or two important "joint" railways, in the working of which the large groups act as partners. The

Photo] [F. E. Mackay

A Result of the London and North Eastern Grouping

A Great Central Engine hauling the "Harrogate Pullman" over the Great Northern Main Line.

L.N.E.R. and the L.M.S. are joint owners, for example, of the extensive Cheshire Lines system, round Liverpool and Manchester, and the Midland and Great Northern Joint Line, which runs across from Peterborough to Yarmouth ; while the L.M.S. and the Southern Railways are similarly concerned in the working of the Somerset and Dorset Joint Line, from Bath across to Bournemouth. These joint railways are still worked as separate concerns, with their own carriages, and (except in the case of the Cheshire Lines) their own engines as well.

In the grouping the Great Western Railway had the easiest task, and has seen the least change. All that it had to do was to swallow up some busy little railways in South Wales—such as the Taff Vale, Rhymney and Barry, which bring the enormous output of coal from the Welsh mines down to the docks round Cardiff for shipment —and also the Cambrian, which threads its tortuous way through Central Wales, and is familiar as giving access to the popular seaside towns of Aberystwith and Barmouth, both of which are now on the G.W.R.

The biggest of all the new groups is the London, Midland and

Scottish, which, as its posters try to make you believe, "takes you everywhere." It certainly does take you nearly everywhere, when you think of Wick and Thurso in the far north of Scotland, Holyhead in the extreme west of Anglesey, Hull on the East Coast of England, and then Bournemouth on the South Coast, and Bristol in the South-west. Not content with that, it owns an extensive line across from Belfast to Londonderry, in Ireland, and a share in a narrow-gauge line which goes even further west on to the wild Atlantic coast of County Donegal.

The chief constituents of the great London, Midland and Scottish group are the late London and North Western and Midland Railways; to them have been added the Lancashire and Yorkshire, North Staffordshire and Furness Railways in the North of England, and the Caledonian, Glasgow and South Western and Highland lines in Scotland. The colour which has been chosen for engines and coaches is the familiar "Midland red"; and all that one regrets in this connection is the disappearance of the beautiful chocolate

Photo] [F. E. Mackay

A RESULT OF THE LONDON, MIDLAND AND SCOTTISH GROUPING

A Lancashire and Yorkshire Engine hauling a West Coast Express on the London and North Western Main Line.

Photo] B [F. E. Mackay

ENGINE NO. 422 OF THE SOUTHERN RAILWAY LEAVING VICTORIA

The Number indicates No. 422 of the "Brighton" Section of the Group.

and white livery of the old North Western coaches, and the "sky-blue" of the Caledonian engines, which is also vanishing.

Next in order, and not far behind the leaders in size and wealth, comes the London and North Eastern Railway. This company is proud of advertising that it serves "The Healthy Side of Britain," and it has, in fact, a virtual monopoly over the traffic to and from the East Coast seaside resorts right the way from Southend round to Inverness. The "East Coast Route"—the old Great Northern, North Eastern and North British Railways, stretching from London to Aberdeen—is the backbone of this group, and with these lines are combined the Great Eastern, Great Central and Great North of Scotland Railways.

After the London, Midland and Scottish and London and North Eastern Railways there comes, third in point of size, the Great Western Railway, which in the old days used to tie with the London and North Western for the distinction of being England's premier

railway. The fourth, in order, is the Southern Railway, comprising the London and South Western, London, Brighton and South Coast, and South Eastern and Chatham lines. There has been a beginning of grouping in Ireland, too, the Great Southern and Western and Midland Great Western Railways having recently combined to make a Great Southern group in the Irish Free State.

It is hard for us to realise the perfectly colossal size of the larger of these concerns. The L.M.S. operates 7,525 miles of railway and the L.N.E.R. 6,715 miles, while the G.W.R. can boast of 3,800 miles and the Southern of 2,200 miles. If all the L.M.S. lines, including sidings, were taken singly and laid out end-to-end, they would make a total of just over 20,000 miles, or five-sixths of the distance required to girdle the earth !

The extent of the engines, carriages and wagons possessed by

Photo] [F. E. Mackay

CARLISLE TO LONDON EXPRESS, L.M.S. RAILWAY

The London and North Western Engine is in the new L.M.S. Group Colours, with the big Number on the Tender ; the Fifth, Sixth, Tenth and Twelfth Coaches in the Train are also painted in the new L.M.S. Red Livery.

each railway group is best realised by noting some of the numbers that they are now beginning to carry. On the L.M.S. line the first five thousand engine numbers are reserved for Midland engines; from 5,000 to 9,999 we find London and North Western engines; then follow Lancashire and Yorkshire engines from 10,000 up to 12,999; and the numbers of the Scottish engines begin at 13,000! The actual number of L.M.S. engines is just over 10,000—about 10,330, to be exact. During the year 1923 these engines between them actually ran a total of some 226,000,000 miles in service, or more than the engines of any other railway in the world, and this within the confines of our little island of Great Britain!

On the London and North Eastern the total number of engines is 7,410; but the proportion of very large and powerful locomotives in this case is rather greater. The Great Western Railway owns 4,000 engines and the Southern 2,250 in round figures.

And what about carriages and wagons? Of passenger coaches the London, Midland and Scottish Railway owns roughly 27,000, the London and North Eastern 20,000, and the other two groups 10,000 apiece! When we come to goods wagons, the figures are simply staggering. Think of them: 325,000 L.M.S. wagons, 299,000 L.N.E. wagons, all but a 100,000 on the Great Western and 40,000 on the Southern! Running a railway in these days is a colossal business indeed.

Gradually the designs of engines, coaches and wagons will be standardised within each group, and though this will mean that the individuality of each of the old lines, which made the study of railways so fascinating in the past, will to a certain extent be lost, yet uniformity in the rolling stock makes for economy in building and in maintaining. For the present, it is most interesting to see engines being tried far away from the lines on which they used to run, and this will be brought home to you by the photographs in

By courtesy] [Underground Rlys.

TUNNEL SIGNAL AND AUTOMATIC TRAIN-STOP
LONDON UNDERGROUND RAILWAYS

this article, which show some " strangers " at work on what used to be the London and North Western and Great Northern main lines.

SAFETY ON THE TUBES

(Photos by courtesy of the Underground Railways of London)

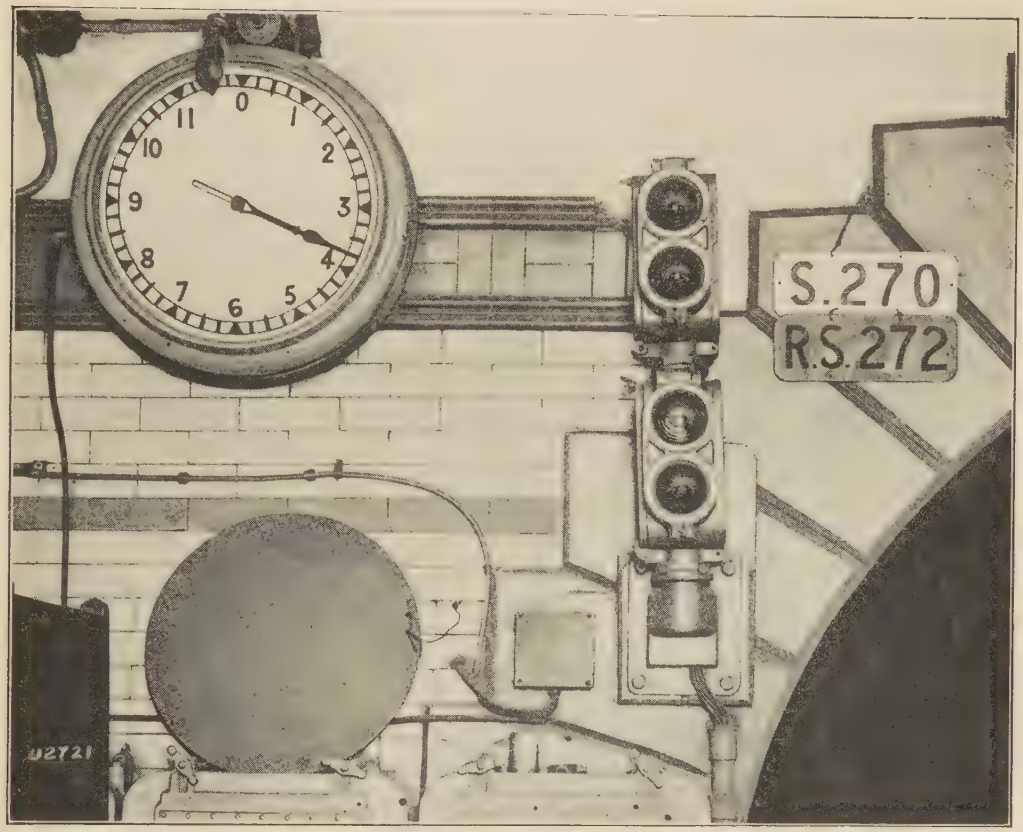
ON no other railways in the world, in all probability, has the working of the trains been brought to so wonderful a degree of safety as on the Underground Electric Railways of London. By their kindness I am able in this article to illustrate some of the remarkable devices by which safe travelling is assured.

At the few places where there are tube railway junctions, some very special signalling equipment is provided, as you can see in the photograph of Camden Town Junction box on page 12. Very small signal and point levers are needed, because the signalman makes all these movements by the aid of electricity.

And in order that he may know exactly the position of any train in his " section " (even though elaborate electrical locking prevents him from making any mistake in the signalling), the complicated diagram at which he is looking shows, by means of little electric lights which light up for a moment, in succession, when each train enters the section, where it is during its passage through, and when it leaves.

There is no room in the tube tunnels for the type of signal with which you are probably most familiar, having a pivoted arm that goes down or up. Where the tube lines come to the surface outside London, such signals are used, in order that they may readily be seen in the daylight. But in the darkness of the tunnels, the signalling is carried on entirely by lamps.

One of these lamp signals, right inside a tunnel, is shown in the full-page photograph on page 7, and by the side of it, against the track, you will notice a small apparatus with an arm pointing upwards. It is only in this position when the signal is at " danger " ; and if the driver of a train should accidentally pass the signal when

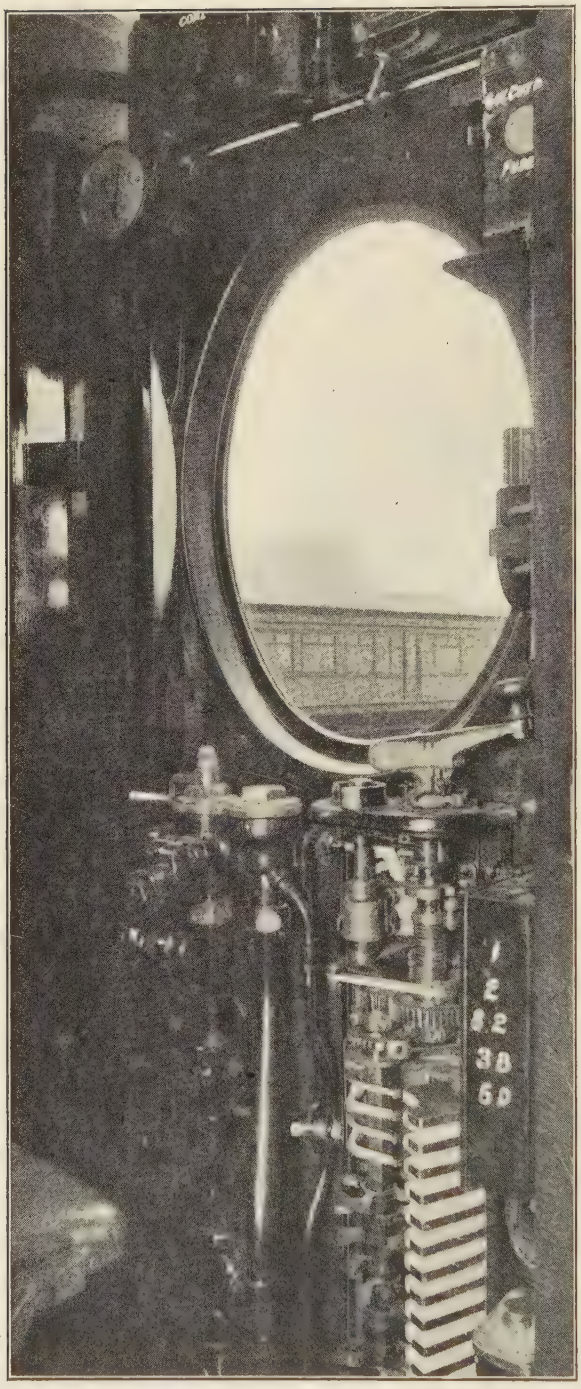


SIGNALS AND HEADWAY CLOCK AT A TUBE STATION

at " danger," this little arm would catch a trigger on the motor-coach of the train, cut off the current and apply the brakes. So the train is certain of being brought to a stand. When the signal is at " clear," and a green light is showing instead of red, the arm of the apparatus falls out of action, and the train trigger passes untouched.

Notice in this picture, too, the two wires near the roof of the tunnel on the right-hand side. If any mishap should occur, and these wires are brought together, the contact cuts off the current from the " live " rails, and sounds warning hooters in the adjacent stations, so that the passengers may be quickly brought to safety.

Then, except at junctions, the signals themselves work automatically. As soon as a train begins to pass a signal, the signal



THE DRIVER'S COMPARTMENT IN A TUBE TRAIN
The " Deadman's Handle " is immediately under the Window.

goes to " danger," and remains at " danger " until the train has passed the next signal ahead, and put that to " danger," when the first signal changes again to " clear." All this is done, of course, by electrical means. In this way, and by the use of the automatic " train-stops," collisions are well-nigh impossible.

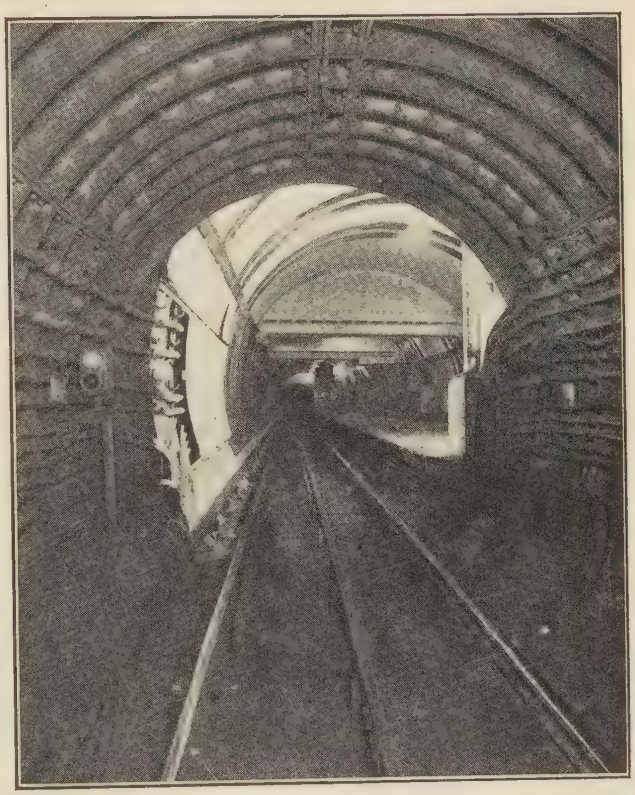
Not only so, but it is possible, with perfect safety, to work the trains so close behind each other, that frequently an electric train is in sight of the next one ahead. On certain of the most-used sections of the Underground, over forty trains are worked per hour over the same metals, when the morning and evening traffic is at its busiest. This is the real secret of its capacity to carry so many millions of passengers.

Other special precautions are also taken in order to make the working absolutely safe. There is first of all the " headway clock " illustrated on page 9. This stands at

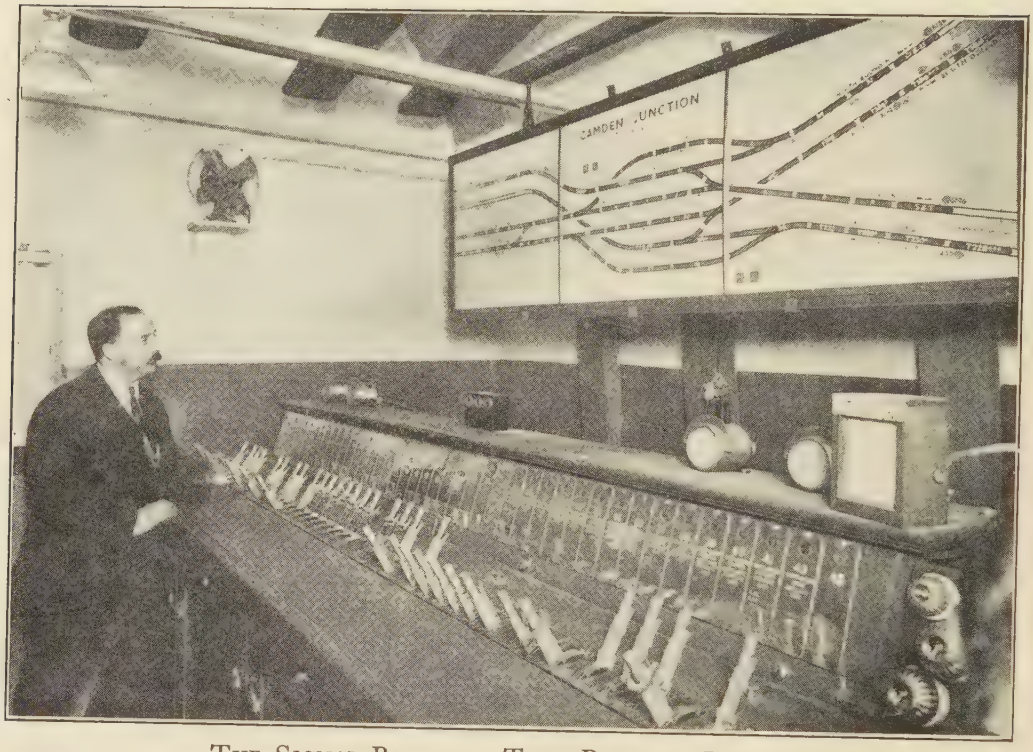
the entrance of the tunnel, and as a train passes it, the hand flies back to " 0," and immediately begins to move round the dial again. In this way, as the driver enters the tunnel, he knows exactly how far the next train is in front of him.

Then the danger has been provided against—a very unlikely danger, it is true, and yet a possible one—of a driver falling asleep, or having a seizure, or even dying at his post. In the picture of a driver's or " motorman's " compartment on the opposite page, you will notice the handle almost exactly under the oval window which gives the motorman his look-out ahead. This handle is the " controller," which allows the current to pass to the motor, and being on a spring, it has to be pressed down in order to do its work. Should the driver's hand leave the controller, the handle springs up, and the current is cut off.

If anything were to happen to the driver of a steam locomotive, it would be noticed immediately by his fireman, but there is, of course, no fireman on an electric train. So this device, which goes under the rather gruesome name of the " deadman's handle," provides against any such unfortunate contingency. Another very interesting picture reproduced on this page shows exactly the view



What the Tube Driver Sees as He Approaches a Station



THE SIGNAL-BOX AT A TUBE RAILWAY JUNCTION

Notice the illuminated diagram on which the actual position of each Train is shown by Electric Lamps, and the Diminutive Signal Levers, working by Electric Power.

that the driver of a tube train gets from the tunnel, as he is approaching a station.

WHERE THE "IRON HORSE" IS STABLED

EVERY locomotive engine is attached to a "stable," and like its brother who works on the roads, the "iron horse" is returned to its stable, or "shed," once daily, for the necessary cleaning and attention.

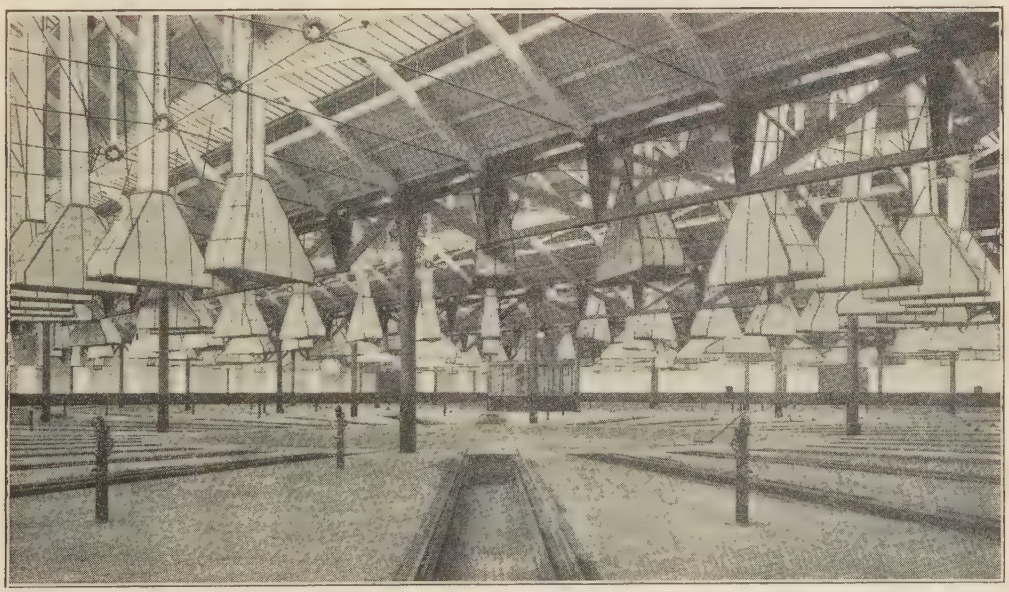
Engine-sheds are chiefly of two different kinds. Sometimes all the lines on which the engines stand are parallel; but at other times there is a turntable in the centre of the shed, and from this all the lines radiate, as in the picture on the next page. The latter type of

turntable shed makes it rather easier to get an engine out when it is wanted for duty, without disturbing a number of others.

Between each pair of rails, as you can see, pits are arranged, so that the men can work underneath the engines if necessary; and special hoods are fitted above the tracks in order to carry away the smoke and steam from the engine chimneys.

When an engine comes into the shed after a run, the fire is raked out, or "dropped," and the cinders have to be shovelled out of the smokebox. Then follows the important duty of cleaning the boiler tubes, which is done by means of a steam jet; if this were not done regularly, deposits of soot would gather in the tubes to such an extent that the engine would refuse to steam properly. Cleaners then take charge of the engine, and with the help of special oil and water, and a slab of bath-brick if necessary, remove all the dirt they can from both the paint-work and the machinery.

Once a week the boiler is "washed out," and by this job—taking several hours—the "fur" is removed from the inside of the tubes,



By courtesy] INTERIOR OF AN ENGINE-SHED [G.W.R.

and the steaming of the engine is further improved. Once a month the boiler has to undergo a thorough examination, as well as the water and pressure gauges, and the brake-gear, while other parts of the machinery come in for similar attention at longer intervals.

CARRYING THE MAILS

SOME of the most interesting trains in the country are those which carry the mails. In the old days the mail trains were the best and fastest by which passengers could travel; to-day the postal business is so enormous that in the case of the more important night mails, there is no room for passengers at all. Such a train, for example, is the famous "West Coast Postal," which leaves Euston terminus for Scotland every evening at half-past eight, and carries all the Scottish mails from London and many other parts of England.

Up to the very last minute before starting Post Office motors and carts come dashing up from all over London, and shoot their contents into the long train of mail-vans. Parcels go into big open vans, where they can be easily handled; but letters go into what are known as the "sorting tenders," which have long benches down each side, and enormous racks above with hundreds of pigeon-holes.

Then, as soon as the "right-away" is given—and when you probably are fast asleep in bed—the whole train becomes a hive of activity. Bags are emptied out; and letters are sorted and tossed into their right pigeon-holes—according to where they are addressed—almost quicker than your eye could follow them.

The first stop of the "Postal" is at Rugby, eighty-three miles down the line, but there are also other important towns on the way, such as Watford or Bletchley, that want to send their letters to Scotland. As the train gets further down the line, too, all the towns

By courtesy] [G.W.R

THE POSTMAN HANGING UP HIS BAGS

and villages passed by the " Postal " are anxious to receive their dispatch of letters from London. How are these exchanges to be made without stopping the proud " Postal " on her course ?

If you could squeeze yourself into one of the sorting coaches, well out of the way, you would be able to see the preparations made as the train approaches one of these places where letters are to be exchanged. The bags full of letters have been done up into stout leather pouches, as they are going to be roughly handled ; then the pouches are hung on to arms fixed on the side of the coach, which are arranged to swing outwards, clear of the side of the train. The last preparation is to open out a great net, made of the stoutest rope obtainable, and normally folded neatly into the side of the sorting coach.

Meanwhile, postmen have been hurrying from the towns or villages towards the apparatus where the letters are to be exchanged. Each postman, too, does his postbags up in leather pouches, and, mounting the ladder of the tall standard by the side of the line, he hangs on his bags, and swings them out towards the line, just as the

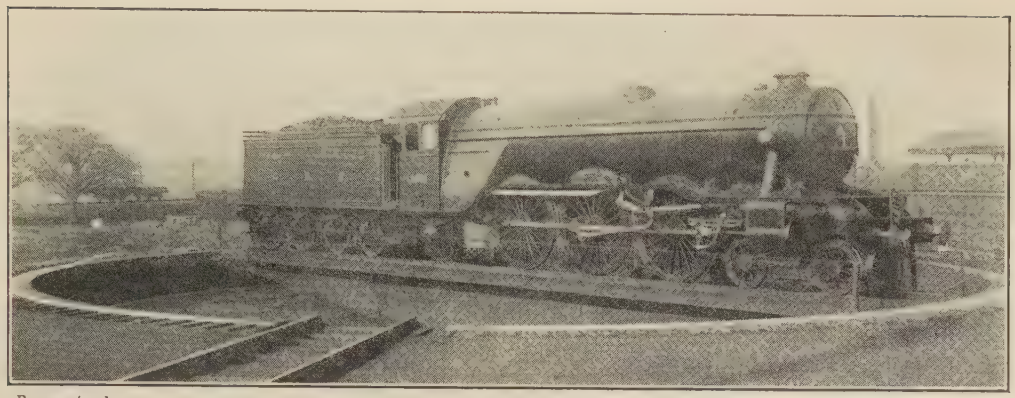
roar of the " Postal " is heard in the distance. On the ground beside the standards you will see the big ground-net, very much like the net at the side of the sorting coach on the train.

Now the express, at a mile-a-minute or more, flies past the mail apparatus. In the picture below you can see the actual exchange taking place. The train net has neatly " collared " the postman's bags off the tall ground standard, and the ground-net has just as neatly swept the bags off the arms at the side of the train. In a second it is all over ; and a moment later the postman is carrying his bags of London letters to his village post office, while the busy sorters on the train are pigeon-holing the new letters that have just arrived.

So the work on the " Postal " goes on, right through the night. At only the biggest stations and junctions does the mail train of to-day require to stop ; for there much greater quantities of mail matter have to be exchanged than the apparatus could handle.

Photo] EXCHANGING THE MAILS AT SEVENTY MILES AN HOUR [Loco Publishing Co.

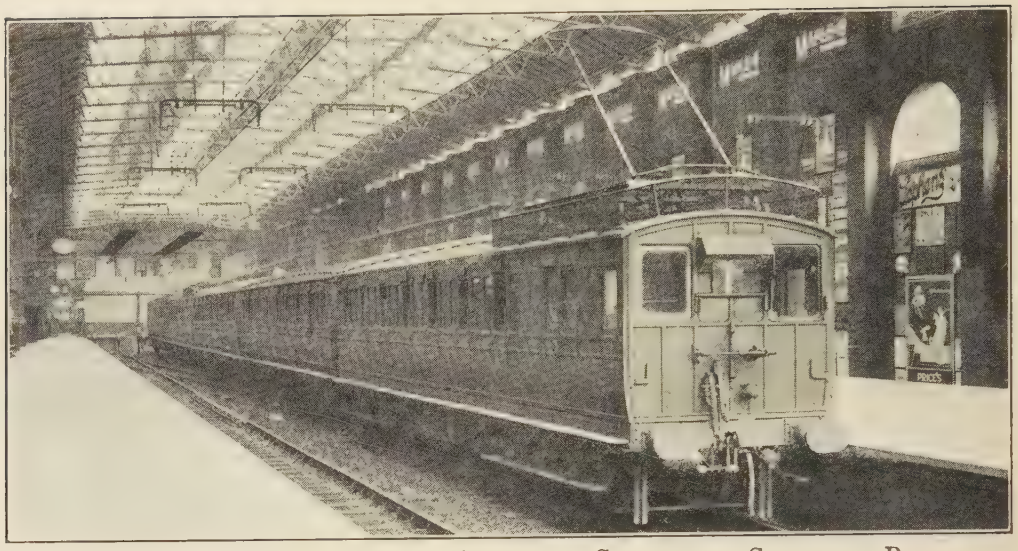
The "Flying Scotsman" Passing Hadley Wood, L.N.E.R.
From photo by F. E. Mackay.



By courtesy] A 70-Foot Locomotive Turntable [Ransomes & Rapier, Ltd.

TURNING LOCOMOTIVES ROUND

AT the end of each long journey, a tender engine requires to be turned round in order that its chimney may be in front for the trip back home again. Here you see one of the big London and North Eastern "Pacifics" on a 70-foot turntable, as nothing shorter will accommodate an engine and tender of such a length. Indeed, at one or two points on the London and North Eastern system, such as York, these engines have to run round a triangle of lines in order to get turned round, the present turntables there not being long enough to turn them. So well is a modern turntable built and balanced that the one shown can be easily moved round, with its 150-ton burden, by the driver and fireman between them. At places where there are many engines to be turned, the table is usually worked by hydraulic or other power, in order to save the labour and time of turning by hand. "Tank" engines, which work the short-distance trains, and so need no separate tenders in which to carry their supplies of coal and water, usually make their return trips with the coal-bunker leading, and the chimney at the rear. Thus the time and trouble of turning them round at the end of each journey is saved.



"Overhead" Electric Train on Brighton Section of Southern Railway

ELECTRIC RAILWAYS

RAILWAY electrification is enormously costly, and when it is complete, there must be a reasonable expectation that the saving in the cost of working the electrified railway will be big enough to pay "interest" on what has been spent in equipping it electrically. Besides that, the fact that there is no further use for all the steam engines on the line cannot be overlooked.

There are only certain conditions, so far as the science of electricity has yet proceeded, in which electrification of railways "pays." In a mountainous country like Switzerland, which has

New Electric Train for South Eastern Section of Southern Railway

By courtesy] [Swiss Federal Rlys.

"Overhead" Electrification on the St. Gotthard Railway

enormous resources of water power, the rushing water in the valleys can be harnessed to drive dynamos, and electricity is thus produced at a very small cost. Thus the Swiss are now in course of electrifying all their railways, and the work is well on the way to completion.

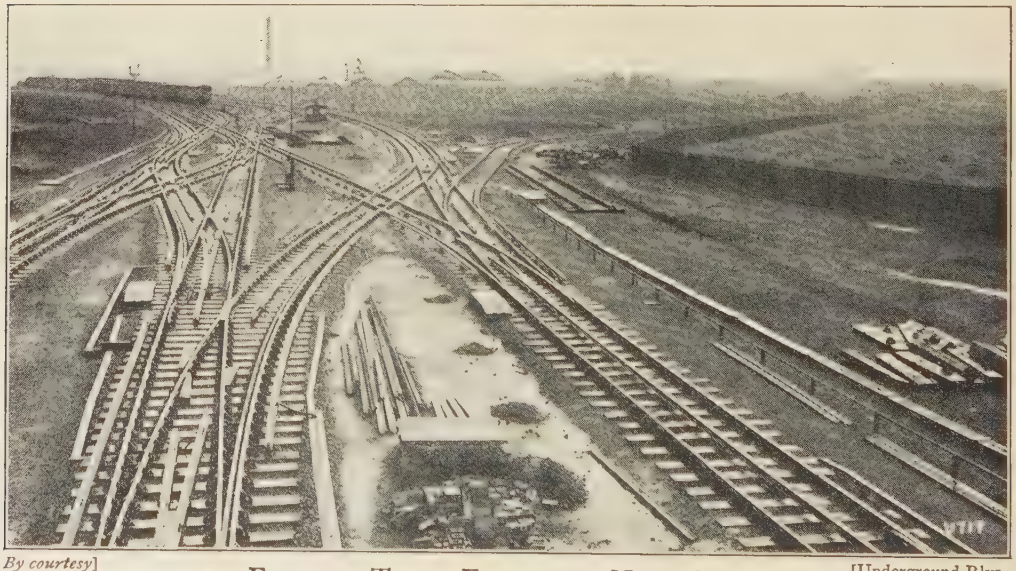
Then, again, where the gradients are steep and the loads are heavy, so that two, or even three, engines have to be used together, electrification pays, because it is possible to cut down the number of engines and crews in service, and to speed up the trains. Mountainous country, heavy gradients and water power generally go hand-in-hand, as in the case of the St. Gotthard Railway of Switzerland, illustrated on this page.

Then, again, electrification pays in the case of very dense suburban passenger services, such as those all round London. Electric trains can get up speed very much quicker than steam trains, and electrification thus results not only in faster suburban trains, but in the possibility of putting many more trains on the line, so saving the expense of laying more tracks. On parts of the electrified "Inner Circle," and on some of the tubes, there are to-day over 40 trains running per hour on some sections at the

busiest times, on the same line of rails, whereas the most that has ever been done with steam is 24 trains to the hour, and this is quite an exception.

The earliest electric railway of any importance in the world was the City and South London tube, from the Bank down to Clapham Common, opened in 1890. On this line separate electric locomotives were used, and the example was at first copied by the " Twopenny Tube," in 1900, but both have since changed over to the use of motor-coaches, as is generally the method on British electric railways. Trains are made up in " units " of two or three cars each, each unit having its own motor or motors, and all the motors on the train are controlled by the one motorman, the train itself being actually driven at several points along its length.

Separate electric locomotives are used, however, when trains without electrical equipment are required to run over the electrified lines, such as the Great Western trains which run round the " Circle " to Aldgate. Similarly, on electrified main lines, the independent



By courtesy] ELECTRIC TRACK EQUIPMENT NEAR ACTON [Underground Rlys.

London Tube Railway Electric Motor-Coach

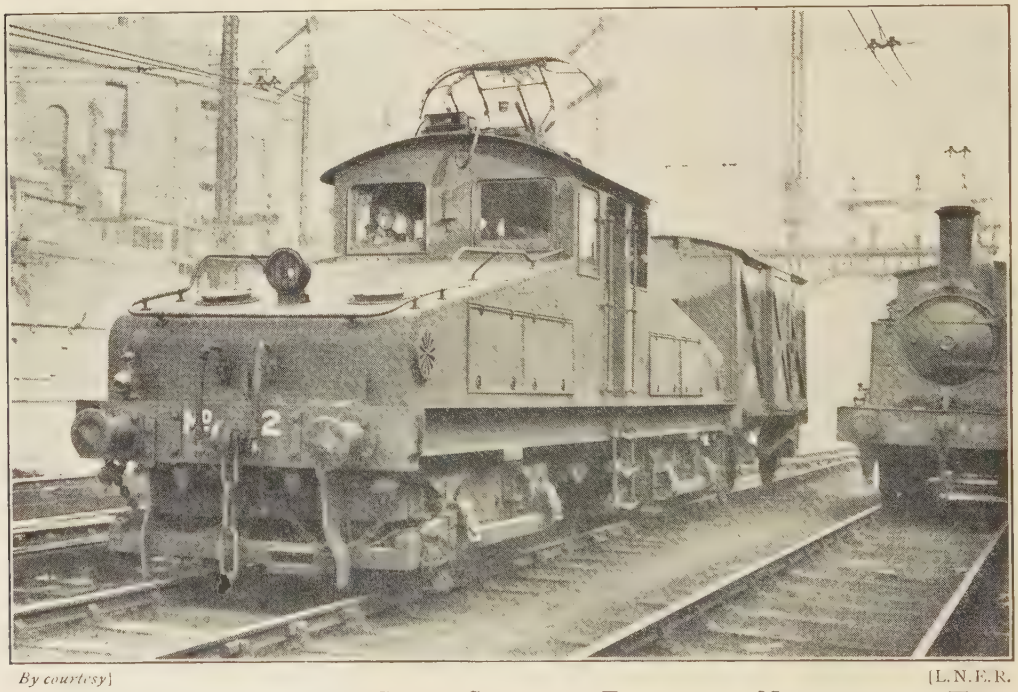
electric engine is always employed, so that any type of passenger or goods rolling stock may be used in the making up of the trains. Electric engines, too, are coming into use for shunting purposes, as in the case of the L. & N.E. engine at the end of the chapter, which works up a very steep incline from the Tyneside quay up to the high level at Newcastle.

You will notice in the photographs the two distinct methods that are used for supplying the electric current to the trains. One is the " overhead " system, and the other the system known as " third rail." Of the two the overhead is generally the cheaper to instal, but in this country, owing to the tight " fit " of our coaches under bridges and tunnels, the use of overhead equipment has presented considerable difficulties.

The only British lines of any importance with overhead electrification are the London suburban lines of the Brighton section of the Southern Railway, the Midland, Lancaster and Heysham line of the L.M.S., and a London and North Eastern branch carrying a heavy mineral traffic from the mining area of south-west Durham down to Middlesbrough. Practically the whole of the extensive

railway electrification in France, Switzerland, the United States, and other countries, has been carried out on the overhead principle. The trains collect their current by means of overhead trolley-poles, like those of tramcars, only of the bigger " bow " type.

In the third-rail system, the motors collect current from a third rail, like one of the track rails, and placed sometimes between them and sometimes at one side of the track, by means of a " brush," which slides along the electrified rail. As electricity has to complete a " circuit," in order to do its work, the current must be returned to the power station after passing through the motor ; this is either done through the ordinary track-rails, on which the trains run, or else a fourth rail is laid down, as in the picture on page 20, for the return of the current. The fourth rail is laid on one side of the line or the other, as may be convenient, and the complication that it lends to electric track is well illustrated by that photograph.



By courtesy [L.N.E.R.

THE RIVALS—ELECTRIC AND STEAM SHUNTING ENGINES AT NEWCASTLE-ON-TYNE

[*Photo* HEAVY YORKSHIRE COAL TRAIN ON L.M.S. RAILWAY [F. E. Mackay

GOODS TRAINS AND THEIR WORKING

THERE are various kinds of goods trains. The wayside goods stops at every little station in order to pick up and drop its wagons, and takes many hours over its journeys ; on the other hand the " express freight " trains, which mostly run in the night, are in these days often timed at speeds but little short of the express passenger speeds to which the passenger is accustomed. This applies especially to fish, and other " perishable " traffic, which has to be carried in wagons fitted with the same " continuous " brake as the passenger coaches, so that the driver may be able to pull his train up readily. Otherwise, such high speed would be dangerous.

In the ordinary goods train, although each truck has its hand-brake, such brakes can only be used in shunting, as there is no means of getting at them when the train is in motion. So the only brake-power then available is on the engine and tender, and on the guard's van at the back, which explains why a goods train takes so long to pull up.

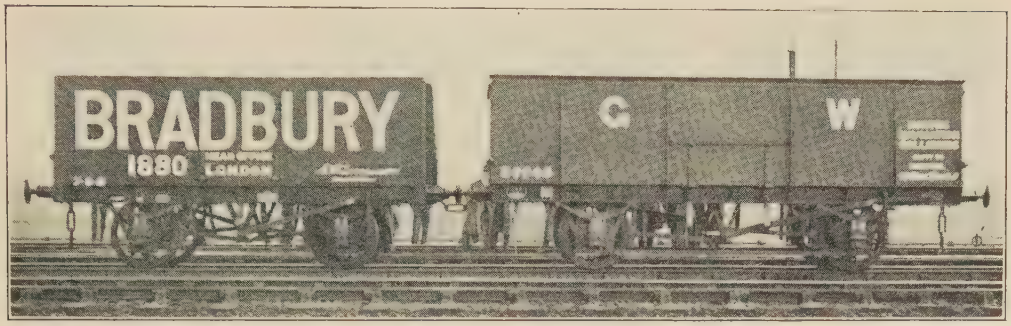
Americans sometimes laugh at our " toy " wagons, as they call

A 2000-ton Goods Train on the Great Indian Peninsular Railway

them, but it has been proved by experience that, for the small consignments and short "hauls" of this country, the four-wheeled wagon has its advantages. Efforts are being made in this country, however, to get the users of the wagons to agree to the employment of wagons of higher capacity.

The Great Western Railway, for example, has introduced the all-steel wagon on the right-hand of the picture at the top of page 25, and is offering specially cheap rates for carrying their coal to the collieries that agree to its use in place of the smaller standard type of wagon on the left. The big wagon takes 20 tons of coal, and the

1250-ton Indian Goods Train Climbing the Ghauts, G.I.P. Railway
Notice the two "banking" engines, one in the middle and one at the end of the train



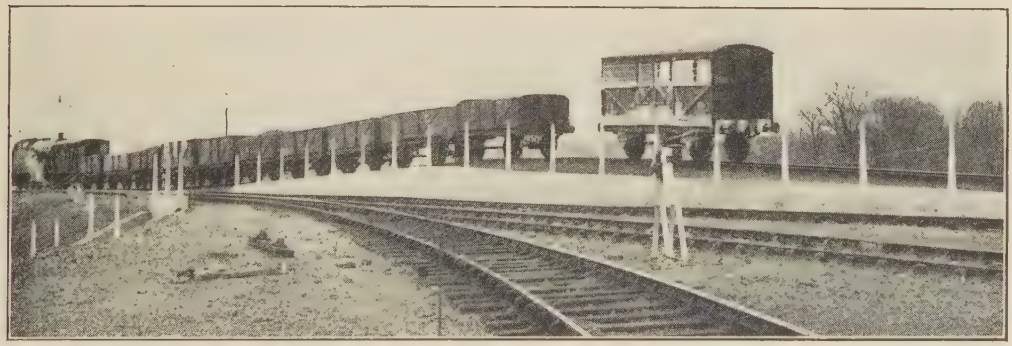
By courtesy] "Railway Gazette"

THE OLD AND THE NEW ON THE GREAT WESTERN RAILWAY

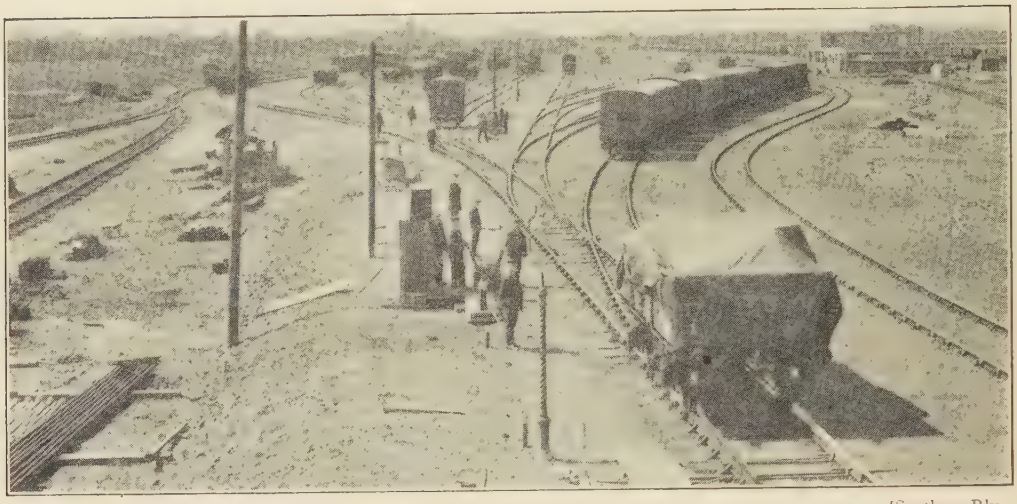
smaller at most 12 tons ; so in every 10 tons' weight of coal carried, $1\frac{1}{4}$ tons' weight of truck is saved, which is a considerable figure on a big train.

All the freight wagons used in America are carried on eight wheels, and capacities of 50 and 60 tons are common. Similar wagons are coming into use in India, as you can see in the picture at the top of page 24. On certain American lines carrying a heavy coal traffic for shipment, wagons up to even 100 and as much as 120 tons capacity, carried on 12 wheels, have been built. "Bogie" goods wagons have also been built in this country, and familiar examples are the 50-ton Great Northern wagons which have been built to deliver bricks from the big brickyards round Peterborough.

The photograph below shows how goods trains are "sorted" in

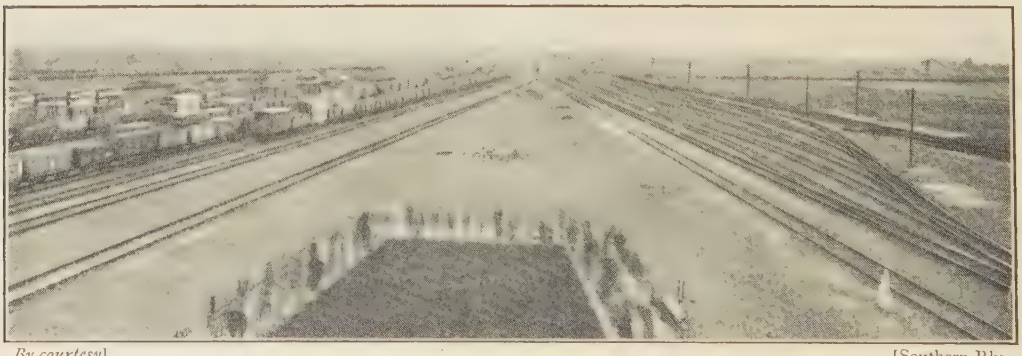


By courtesy] ONE OF THE "HUMPS" IN FELTHAM YARD [Southern Rly.



By courtesy] WAGONS RUNNING OFF A "HUMP" AT FELTHAM [Southern Rly.

the big marshalling yards, according to the destinations of their wagons. Each train is pushed slowly over the "hump" in the track, which can be seen in the distance; at the top of the hump the wagons are uncoupled one by one, and roll quickly down a short gradient to the beginning of the "gridiron" of sidings, where each wagon is deftly turned by the hand-points into its own road. Every siding represents a different destination, or collection of destinations, and by this method of sorting the trains, much time and labour in shunting is saved.



By courtesy] [Southern Rly.

THE GREAT SOUTHERN RAILWAY SORTING SIDINGS AT FELTHAM

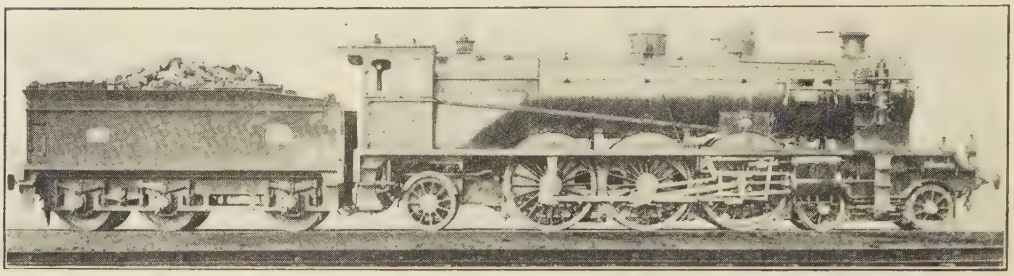
By courtesy] "GARRATT"-TYPE ENGINE, BURMA RAILWAYS ["Railway Gazette"

LOCOMOTIVE GIANTS OF OTHER COUNTRIES

MOST of the other countries in the world have learned wisdom from our railway experience, and have left more room round their tracks than we have. Thus the engines that are built on the Continent, and particularly those of the United States and Canada, are generally considerably larger and heavier than our locomotives in this country, though the distance between the tracks is practically the same as it is here.

The vast freight engine of the Canadian National Railways, illustrated on page 29, weighs with its twelve-wheeled tender no less than 325 tons, and measures all but 100 feet in length overall; it is capable of exerting 3200 horse-power. It is built to a maximum height of 16 feet, which is 3 feet more than the height of most of our big locomotives in this country, and it is proportionately wider also. The tender has sufficient space for no less than 15 tons of coal and 11,000 gallons of water!

Under it, on the same page, you see how the Americans get over the difficulty of designing enormous locomotives "flexible" enough to take the curves in the track easily. This is really like two 2-8-0 locomotives arranged back-to-back under one boiler; and each 2-8-0 frame is constructed in the form of a swivelling truck. Designed



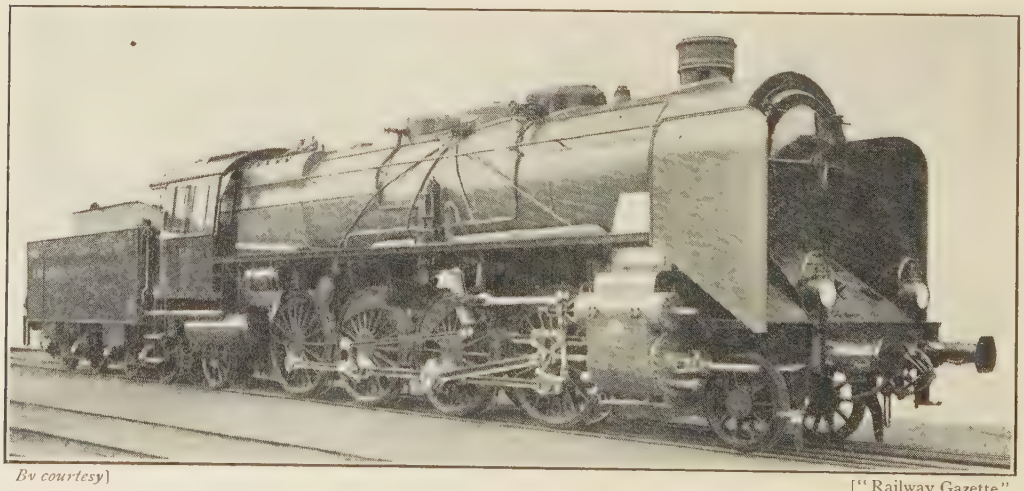
Photo] [Loco. Publishing Co.

COMPOUND "PACIFIC" EXPRESS ENGINE, PARIS-ORLEANS RAILWAY

to pull with a maximum force of $46\frac{1}{4}$ tons, this monster weighs, with its tender, 346 English tons in working order.

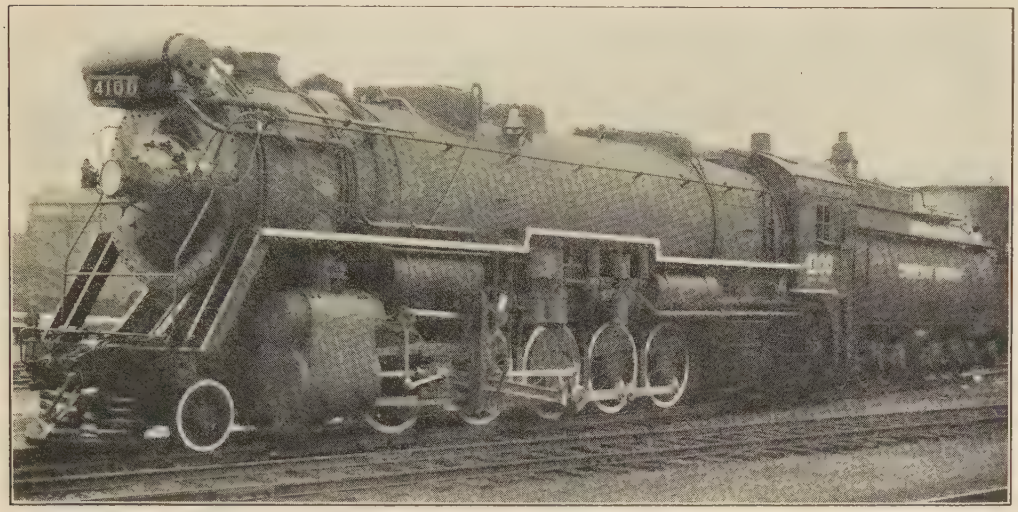
The big "Garratt"-type locomotive of the Burma Railways, at the head of this chapter, is another way of surmounting the flexibility difficulty. In this design the boiler is mounted on a frame like a girder bridge, supported by 2-8-0 engines at both ends, which also carry the coal and water supplies, so that no tender is required. Both 2-8-0 engines, of course, are arranged as pivoted trucks, similarly to those of the American Mallet-type engine just described.

The favourite type of engine for express work, both in America and on the Continent, is the 4-6-2, or "Pacific," of which a charac-



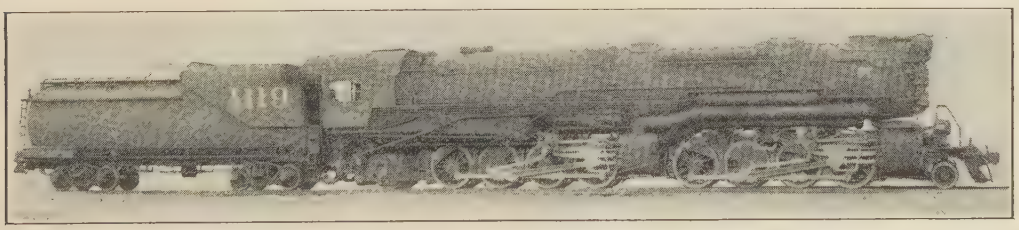
By courtesy] ["Railway Gazette"

COMPOUND 2-8-2 EXPRESS ENGINE, PRUSSIAN STATE RAILWAYS



TEN-COUPLED FREIGHT ENGINE, CANADIAN NATIONAL RAILWAYS

teristic example appears at the top of page 28. But the increasing weight of trains calls for more " adhesion " weight than is obtainable with six-coupled wheels, and in these days the Continental railways are beginning to build eight-coupled engines for express service, like the German engine on that page. This is of the 2-8-2 type, but the latest French engines, on the Est and P.L.M. Railways, are very powerful examples of the 4-8-2, or " Mountain " type. The curious shields in front of the German engine, by the way, are designed to create an upward current of air, when the engine is running, and so to carry the smoke and steam upwards, and so clear of the driver's cab.



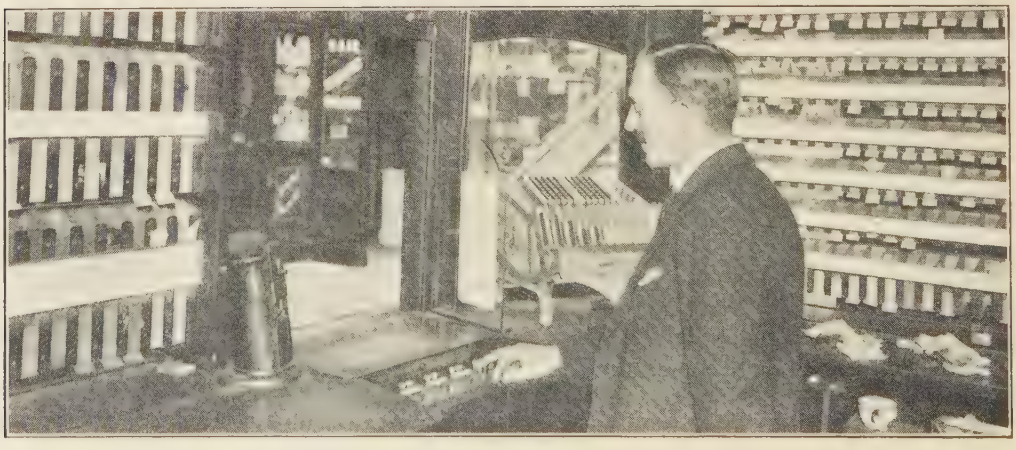
A VAST " MALLET "-TYPE ENGINE FOR THE CHESAPEAKE & OHIO RAILROAD OF THE UNITED STATES OF AMERICA

By courtesy] A Holiday Scene at Liverpool Street Station [L.N.E.R.

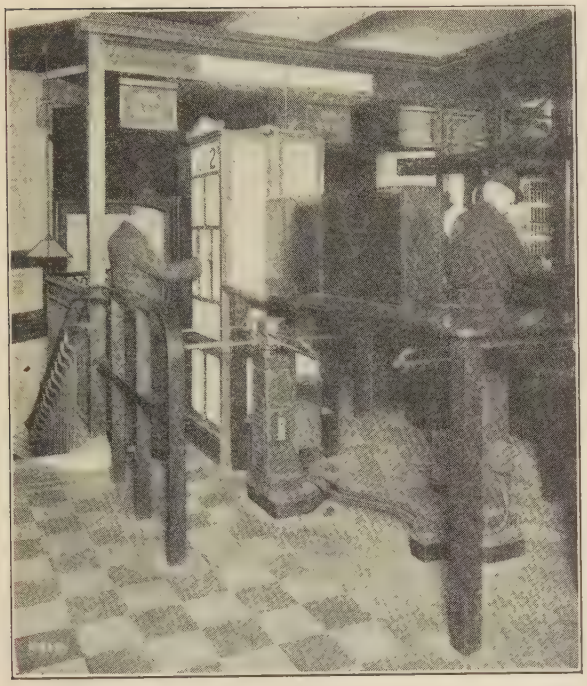
HOW PASSENGERS ARE HANDLED

ROUGHLY two thousand five hundred million journeys are made by railway passengers in this country every year. If their journeys were made at a perfectly even rate, of so many per hour during the day, and of so many per month all the year round, the problem of handling them would not be so severe. But this is not the case.

On the Great Eastern section of the L.N.E.R., whose busy London terminus at Liverpool Street, with its eighteen platforms,



Automatic Ticket and Change Machines at Westminster

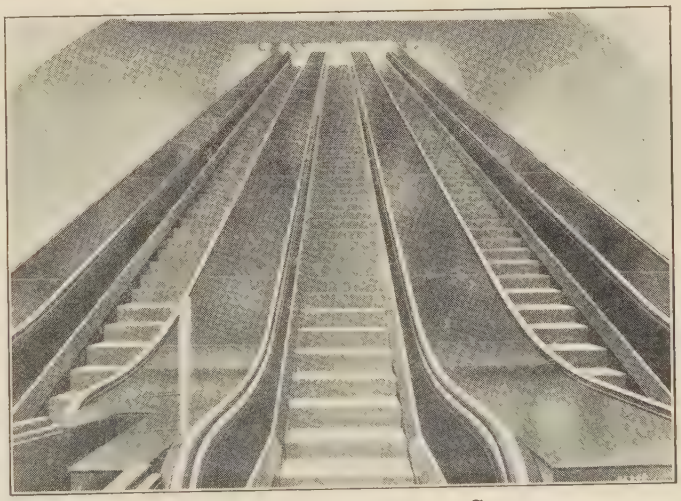


TICKET MACHINE AND TURNSTILE

is shown on page 30, the rush to the bracing East Coast nearly all comes between the middle of July and the middle of September. Not only so, but vast numbers of the holiday-makers persist in wanting to travel on Saturdays, which means a tremendous strain on the resources of engines, coaches and men during this short period.

Then, again, suburban lines experience a tremendous rush in one direction while all the dwellers in the suburbs are going up to the City in the mornings, and then in the opposite direction when they want to be taken home at night. At such times handling the passengers quickly and smoothly calls for the utmost thought and preparation on the part of the railways.

At tube railway stations, for example, the lifts which take passengers down to the railway level are rapidly giving place to escalators, which can

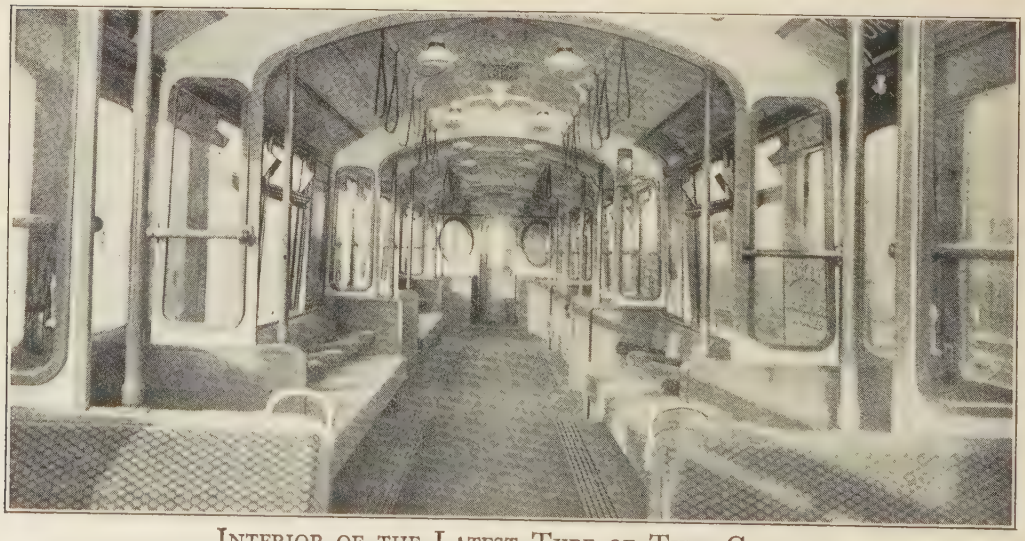


TRIPLE ESCALATOR AT BANK STATION

deal with far more people at one time than can the lifts. One of the latest triple escalators, at the Bank Station, is shown on the previous page; there are three moving stairways, one always going down, and another always up, while the third is " reversible," going either down or up at will, according to the way in which the traffic is " flowing."

As far as possible, tickets on the tubes are issued automatically. At the top of page 31 you see an entirely automatic machine ; while at the bottom of page 30 is shown the automatic assistance given to a booking-clerk. The tickets mostly asked for at this office appear in little slots, properly numbered, dated and clipped, as the clerk presses the right button ; and the right-hand machine automatically gives out the correct change. Round him in the large cases are the tickets to more distant points, for which there is less frequent demand.

Tube trains, too, are designed to accommodate the maximum possible number of passengers in a minimum space, with plenty of room inside for them to circulate, and numerous doors, opened and shut by pneumatic power in the latest types, for entrance and exit.



Interior of the Latest Type of Tube Coach

Descending the Stanserhorn—A Swiss Mountain Railway.

The St. Gotthard Railway on the Shores of Lake Lucerne

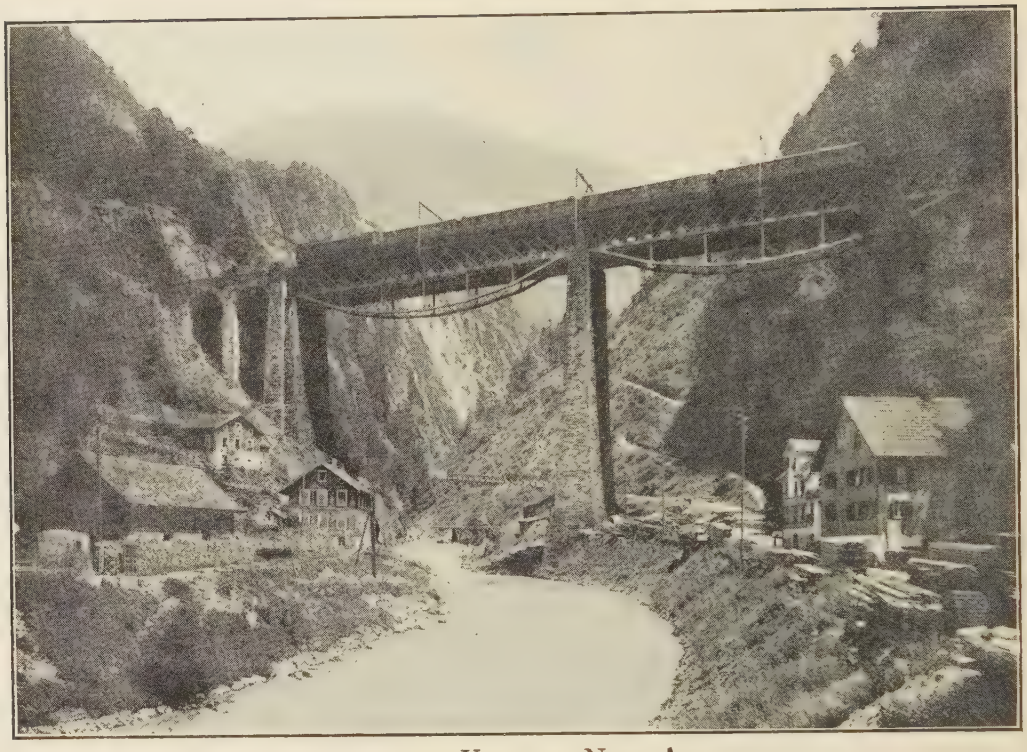
THREADING THE ALPS

The Wonderful Railways of Switzerland

(Photos by courtesy of the Swiss Federal Railway)

IF in our own country the railway engineers have at times had difficulty in overcoming the obstacles that Nature has placed in their way, their difficulties have been small indeed as compared with those which have faced the Swiss engineers in laying their railways through the Alps. Right across their country lies this immense range of mountains, reaching heights of 13,000, 14,000 and even 15,000 feet.

Switzerland, too, is one of the central countries of Europe, and several of the most important European main lines pass through it, either from east to west, or from north to south. Each of these lines must, somehow or other, thread the Alps; and in planning their



KERSTELENBACH VIADUCT, NEAR AMSTEG

routes the engineers have had to fight Nature tooth and nail in order to lay their lines. Even then many of these railways are so steep in their gradients that tremendously powerful locomotives have to be used to surmount them ; and, of course, the cost of their construction has been immense.

Let us just travel in thought over one of these lines, so that we may see in how marvellous a way the difficulties have been overcome. The most interesting is probably the St. Gotthard line, running southwards from the Lake of Lucerne down to the Italian frontier at Bellinzona, and opened in 1882 ; over it passes all the traffic from Belgium, Eastern France and Western Germany down into Italy. We will imagine we have got into one of the St. Gotthard trains at Lucerne, and are travelling southwards.

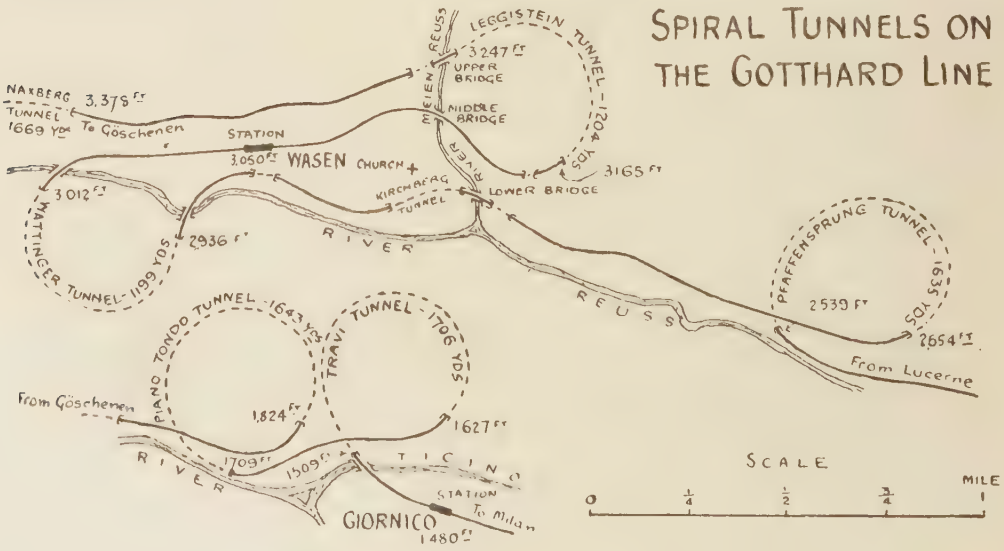
The first picture, at the head of this chapter, shows the line

winding around the shores of the lake ; after leaving Fluelen, the village seen ahead of us, we are going to head into the valley of the River Reuss, which you can see opening up to the right of the majestic snow-capped peak in the distance—the Bristenstock. Once we enter the valley proper, at Erstfeld, our level running is at an end, and for the next twenty miles the line is going to rise, the gradient being as steep as 1 in 40, without any break.

In the next picture, on the opposite page, the railway has already climbed far, after only $3\frac{1}{2}$ miles of this gradient. This is a branch valley—that of the Kerstelenbach—and the line comes out of the tunnel on the left, and flies over the stream by a viaduct 178 feet high. But although we are far above the rushing River Reuss at this point, and are still climbing, the bed of the river is so steep that

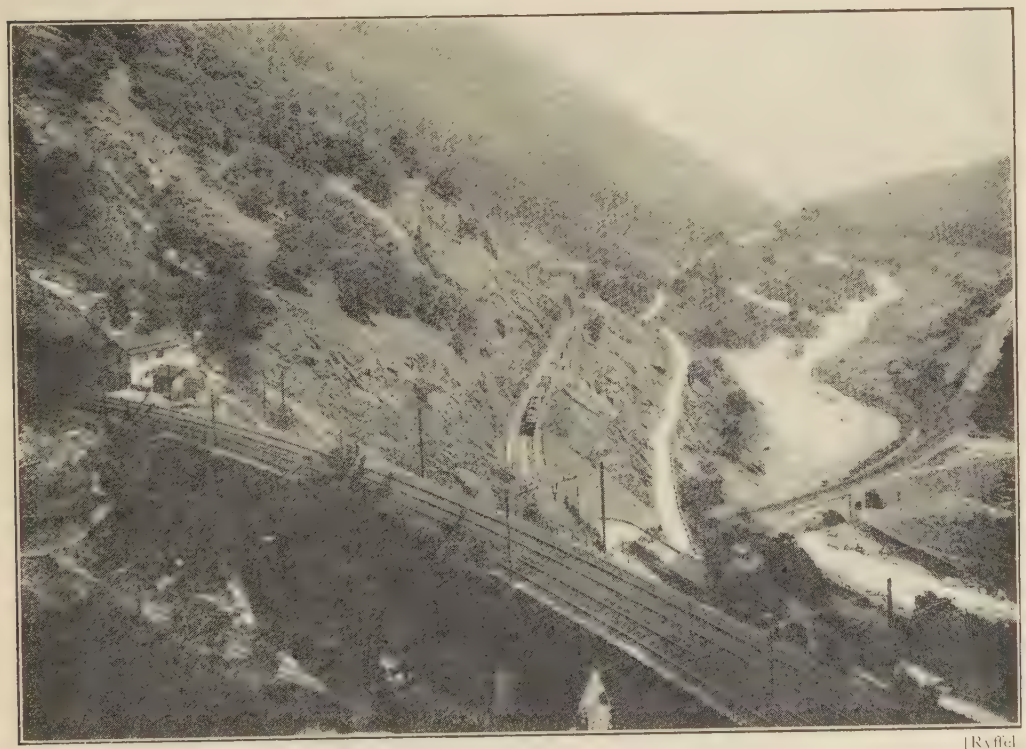
PFAFFENSPRUNG SPIRAL TUNNEL, NEAR GURTNELLEN

THE DOUBLE LOOP OF THE GOTTHARD RAILWAY AT WASEN



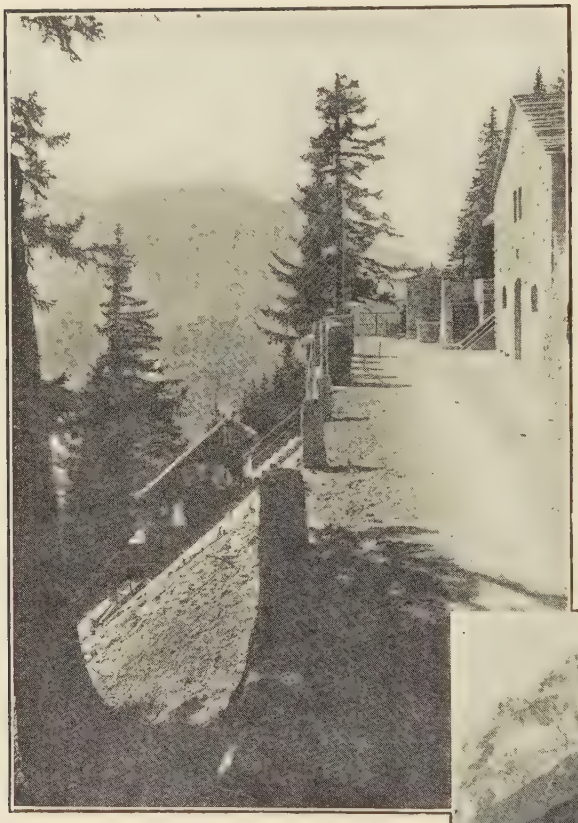
before long we shall find the line nearly down to the very edge of the rushing water.

What did the engineers do next, in order to make their railway rise sufficiently to keep clear of the river, and yet without increasing its gradient ? We shall soon see. At Gurtnellen our train suddenly bears to the right, and dives straight into the hillside. The tunnel is nearly a mile long, and when we come out we are high above the river again, and we can see what appears to be another railway below us. What has happened ? We have travelled round in a complete corkscrew in that Pfaffensprung Tunnel, and the line below us is the actual railway over which we were running three minutes ago ! In the picture on page 35 we see the Bristenstock guarding the valley up which we have come ; we can also see our railway turning,



Photo] [Ryffel

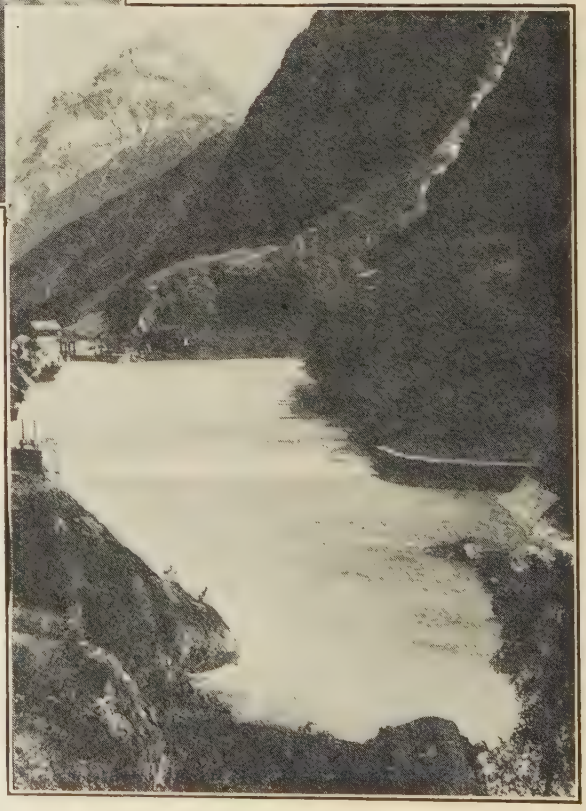
THE WONDERFUL SPIRALS AT GIORNICO



THE STEEPEST RAILWAY IN THE WORLD: THE SUMMIT

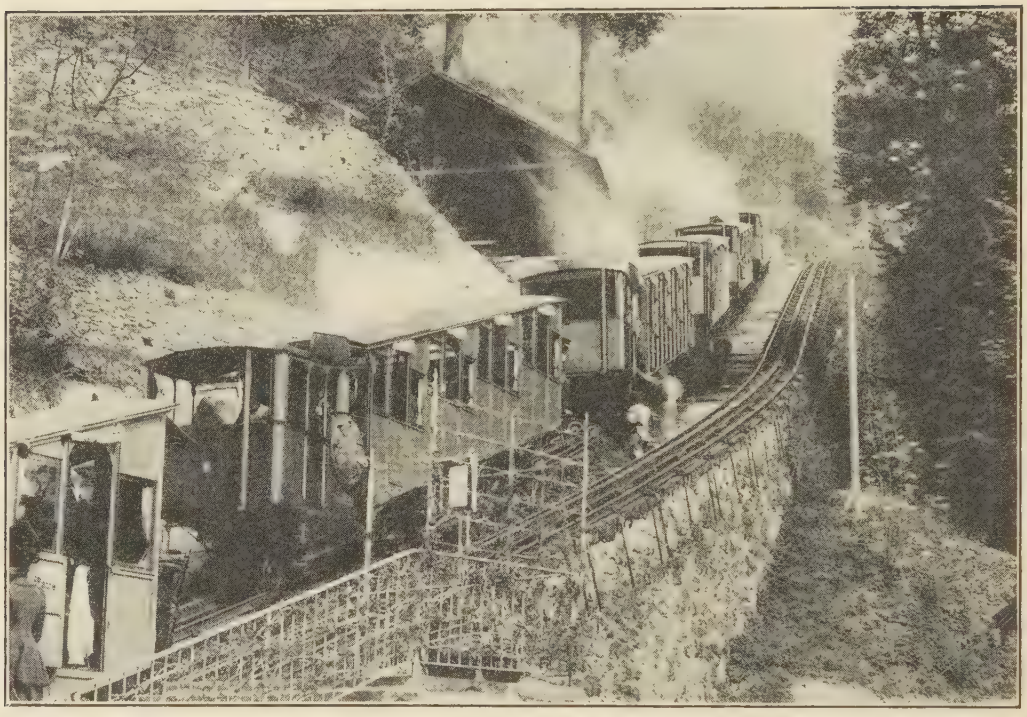
on the lower level, to enter the tunnel; and then, in the foreground, there is the stretch of line on which we are now running, 115 feet higher.

Some still more wonderful planning is to follow. On page 36 you will find a diagram showing the course of the railway in the neighbourhood of the village of Wasen. The tunnel to which I have just referred is on the right of the plan; just after crossing the branch stream known as the Meienreuss, the railway bears to the left, crosses the Reuss, and dives again into the hillside by the Wattinger Tunnel. Emerging after a half corkscrew turn, it recrosses the river, and doubles right back on itself past Wasen, crosses the



WHERE THE WATER IS GATHERED FOR THE GOTTHARD RAILWAY POWER-STATION

BRINGING THE WATER DOWN TO AMBRI-PIOTTA POWER STATION



SIX TRAINS AT THE PILATUS RAILWAY TERMINUS, ALPNACHSTAD

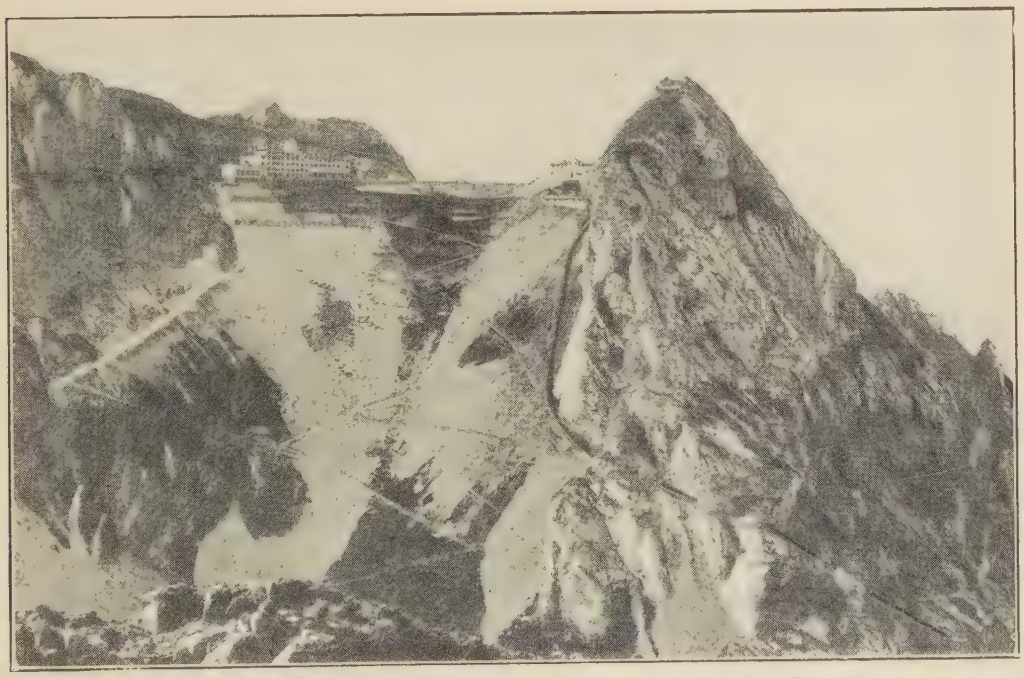
Meienreuss again, by the middle bridge, and then dives into the opposite hillside, to thread the Leggistein Tunnel.

By this fine feat of engineering the line is raised no less than 400 feet opposite this village of Wasen. In the photograph above my diagram you can see all three levels of the railway ; in the foreground is the main road bridge across the Meienreuss, then the lower railway bridge, and above that the middle bridge, and then, high up on the far side of the valley, passing just behind the prominent little Wasen church on its hill, the upper railway level on its way towards Italy.

Four miles beyond Wasen we reach the village of Goschenen. Now the valley of the Reuss contracts into a wild, narrow, rocky gorge, and here the engineers reached the bold decision to carry the surface railway no farther, but to tunnel right under the mountains, in a straight line, until the top of the watershed had been passed,

and they could strike a valley on the south side of the Alps which would carry them down into Italy. You can see the northern entrance of the great tunnel in the coloured plate at the beginning of this chapter ; it took eight years to blast out, through the solid rock, and cost two and a quarter million pounds. It is not the longest of the Swiss tunnels, as it measures $9\frac{3}{4}$ miles in length against the $12\frac{1}{4}$ miles of the Simplon Tunnel. At the centre of the tunnel the railway has attained a height 2230 feet above that at which it passed Erstfeld, only $22\frac{1}{2}$ miles before.

As the train leaves the south end of the tunnel, and descends the valley of the Ticino, there are just as wonderful engineering feats, if not more wonderful ; but I am afraid I have not space here in which to describe them in detail. The spiral tunnels at Giornico, however, must be mentioned. You will find a plan of them on page 36, just below that of the double loop at Wasen ; and a photograph showing



THE SUMMIT OF PILATUS RAILWAY, 7000 FEET ABOVE SEA-LEVEL

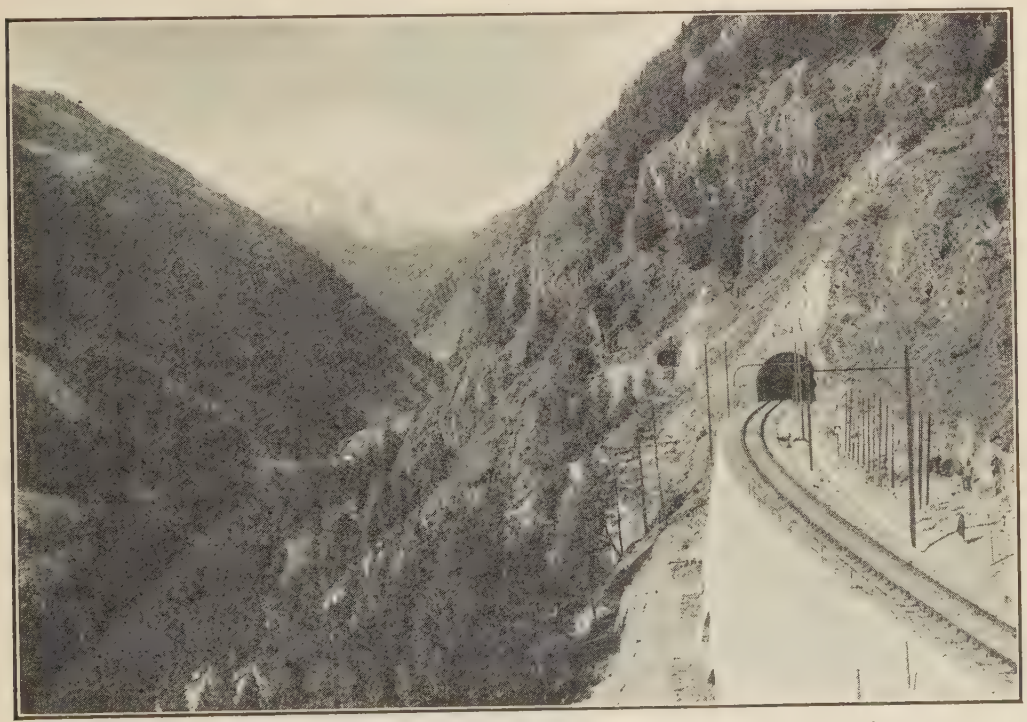
Some Remarkable Engineering on the Lœtschberg Railway

all three levels of the line very clearly is on page 37. The railway is just bending round to the left, in the foreground, to enter the Piano-tondo Tunnel ; in this it will describe a complete corkscrew in the hillside, and emerge on to the second, or middle level, on which the train is seen ; in the distance the line bends round again to enter Travi Tunnel, and performs yet another complete corkscrew turn ere coming suddenly out into daylight and crossing the River Ticino below to enter Giornico Station ! Between entering Piano-

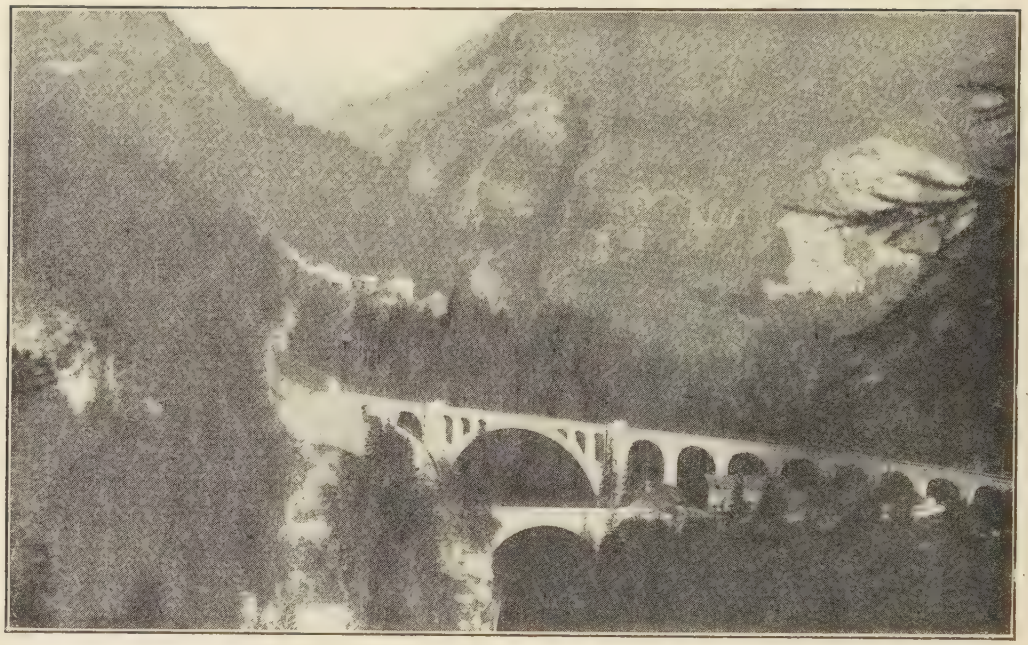
tondo Tunnel and leaving Travi Tunnel, immediately below, the line has dropped as much as 309 feet.

The Swiss railway engineers have at last awakened to the fact that Nature, whom they have had to fight so strenuously, as we have seen, in order to lay their railways, has at least been holding out to them with both hands the means of working their lines. All these years Switzerland has been importing coal from neighbouring countries in order to provide fuel for its locomotives. But now, as is evident in the pictures of the St. Gotthard Railway, the engines are electric. How is the current obtained ? It is made by the use of " white coal "—that is, the water that always runs so abundantly in every mountainous country.

In the lower photograph on page 38 you will see how an artificial lake has been made by damming up one of the rushing streams in



A View on the Lœtschberg Railway, showing Avalanche Tunnels



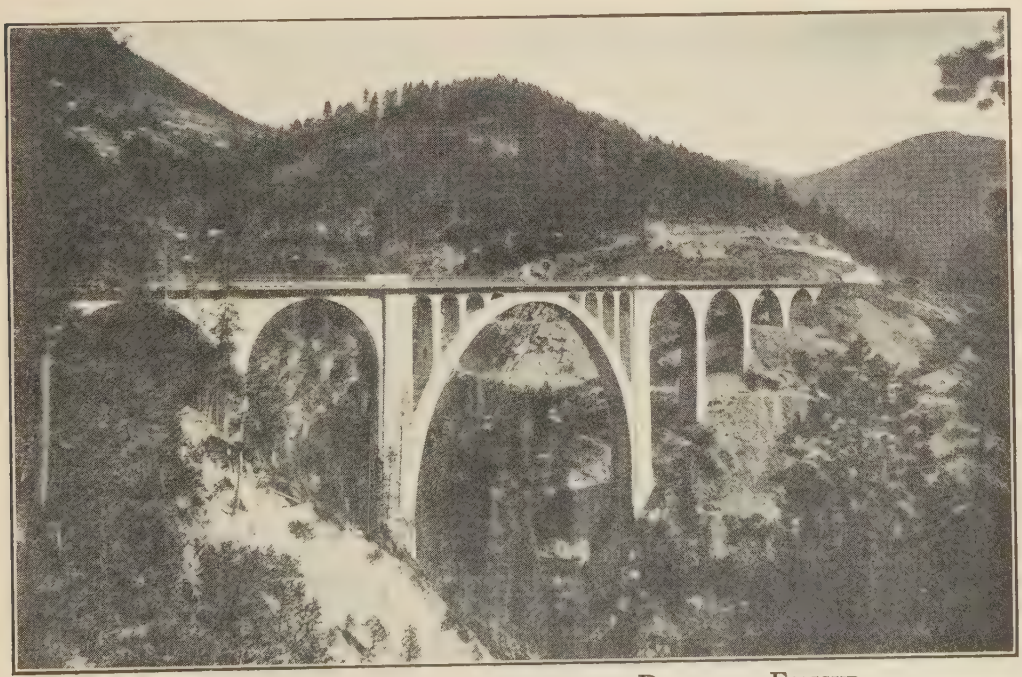
SOLIS BRIDGE ON THE RHÆTIAN RAILWAY

a neighbouring valley, and then, in the striking full-page picture on page 39, the way in which the water is brought rushing straight down by huge pipes into the power-house at Ambri-Piotta. In the power-house the water drives great turbines—a modern development of the principle of the mill-wheels with which you are so familiar—the turbines drive dynamos, and the dynamos produce the electric current for working the railway. All the Swiss railways are now in course of being converted to electric traction, so that the trains may be run with the power thus provided by Nature ; and soon there will be no steam locomotives left in Switzerland.

To the left of the pipe-line coming down into the power-house, you can see one of the " funicular " mountain-railways for which Switzerland is so famous. The upper terminus of the line is shown in the photograph at the top of page 38. This, as a matter of fact, is claimed to be the steepest railway in the world, the maximum

gradient being no less than 87·8 per cent—that is to say, 1 foot up in the air for every 13½ inches in a horizontal direction! The line is ⅞-mile long, and rises 2145 feet in this short distance. Peculiar coaches are used, as the picture shows, so that the passenger may sit on the level, and the "platform" at the terminus consists of a steep flight of steps!

This line is worked by means of an endless cable, the weight of the descending car being used to help pull up the ascending car. In this way the power required to work the line is very much reduced. But the majority of the Swiss mountain railways are worked on the "rack" system. It is impossible to depend on the adhesion between the smooth driving-wheel tyres of the engines and the smooth running rails on such steep inclines; and so a long toothed "rack" is provided between the rails—you can see it in the photograph on page 40—and the engines are provided with toothed driving wheels which



WIESEN VIADUCT, ON THE LINE FROM DAVOS TO FILISUR

The Amazing Loops on the Albula Line of the Rhætian Railways between Bergun and Preda

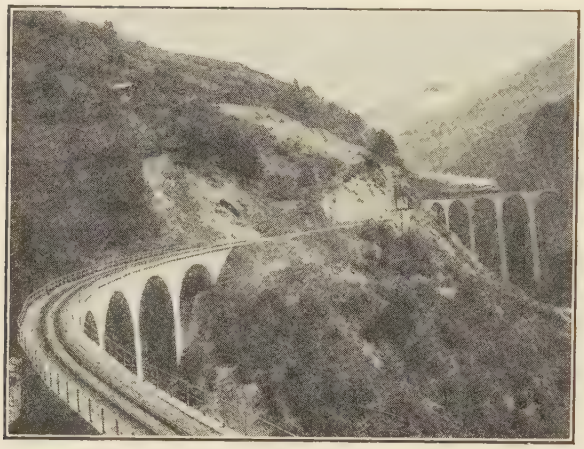
engage securely in the rack without slipping. The ordinary engine wheels are just used for carrying purposes, and nothing more.

The photograph on page 40 shows six " trains "—each of them a combined rack locomotive and passenger coach seating 32 people—about to start from Alpnachstad terminus on the Pilatus Railway, near Lucerne, and that on page 41 shows the upper end of the line. Between the two, in the course of a three-mile journey, the line ascends 5350 feet. Its average gradient is rather steeper than 1 in 3, and the maximum gradient is 1 in 2. It is the proud boast of the Swiss that despite the steepness of these lines, their safety precautions have been so well thought out that no accident involving loss of life has ever occurred on one of their funicular railways.

The highest of all the mountain lines in Switzerland is that which climbs right up to the saddle between the imposing Mönch and Jungfrau, in the Bernese Oberland, the altitude of Jungfraujoch Station being no less than 11,342 feet above the sea, far up into the eternal snows. In view of the impossibility of carrying the line on the ice and snow above the snow-line, the upper part of the railway has been tunnelled inside the face of the mountain, with frequent openings cut out, in order that the passengers may see the views *en route*.

Snow and ice are not only a difficulty in Switzerland on the mountain lines, but those in the valleys often suffer severely in winter-time, when the heavy snows drift on to their tracks, and have to be cleared if communication is to be maintained. Worse than that, a mass of snow sometimes begins to move high up in the mountains, and, gathering force and impetus before it, sweeps away everything in its path. Such is the dreaded avalanche.

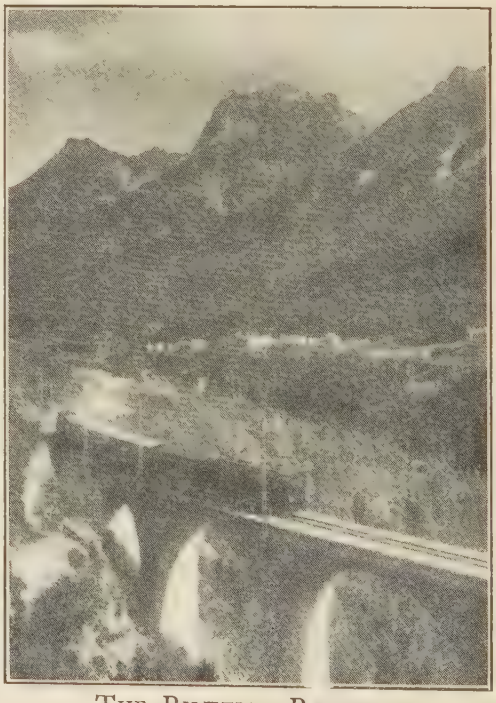
On routes where avalanches are known to be of frequent occurrence, special protection is devised by the railway engineers for their lines. You see an example of this in the photograph of the Lœtschberg Railway on page 43 ; the short tunnels have been constructed



THE LANDWASSER VIADUCTS

expressly to carry avalanches clear over the railway, at points where they are often experienced. The other Lœtschberg picture, on page 42, shows some of the extraordinary engineering of that line, clinging as it does to the precipitous hillside, and carried up the three levels shown by means of spiral tunnels, similar to those on the St. Gotthard line.

The remaining photographs in this chapter are of a narrow-gauge line of wonderful interest in the east of Switzerland, called the Rhætian Railway. With its offshoots, the Albula Railway and the Bernina Railway, it covers the whole of the favourite holiday district known as the Engadine. The photographs will give you some idea as to how gorges have been spanned, and mountains have been climbed. Most astonishing of all are the loops between Bergun and Preda shown in the full-page picture on page 46. This represents one continuous railway, doubling back on itself twice by means of spiral tunnels in order to ascend the steep valley. Such is the railway engineering of Switzerland; it really needs a whole book to itself!



THE RHÆTIAN RAILWAY
NEAR VULPERA—TARASP

Swiss Express leaving the Great St. Gotthard Tunnel.

By courtesy] "LAUNCHING" A GIRDER BRIDGE [Underground Rlys.

PLANNING AND MAKING A RAILWAY

VERY careful thought has to be spent on the planning and making of a railway. It must not be too costly in its construction, or it may never "pay"; on the other hand, if the engineer attempts to make it very cheaply, by laying it more or less over the surface of the ground, with nothing much in the way of embankments and cuttings, viaducts and tunnels, it may be so expensive to work, on account of steep gradients, that it still is unable to pay its way.

So the engineer has to steer a middle course, as well as he can. He takes advantage of the lie of the land offered him by Nature, running his line along river valleys where possible, for example, in order to keep them reasonably level. Then, when he has to cross the valleys, he smooths out his gradients as far as practicable by means of cutting and banking, using the material excavated from his cuttings to make his embankments.

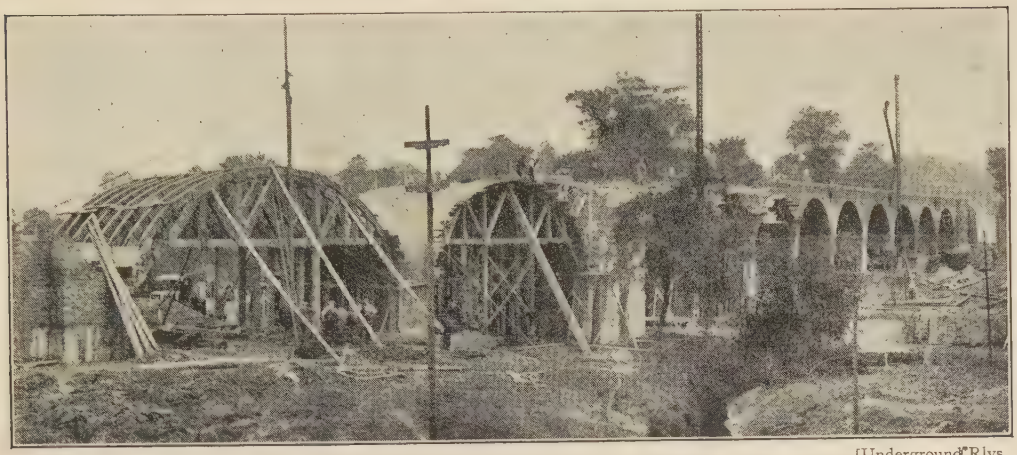
One of the important things in railway planning, indeed, is to see that the cuttings and banks "balance" each other; otherwise it will be necessary to buy extra land, either in order to cut out material to make up the deficiency in the banking, or else to find a

By courtesy] ROADE CUTTING [L.M.S.R.

place on which to dump the surplus soil from the cuttings. The labour of excavating the cuttings is enormously reduced to-day by the use of a steam "excavator," or "steam navvy," as it used to be called; an example of one of these hard workers is shown in the coloured plate at the beginning of this chapter, cutting out the earth in great bucketsful, tons at a time, and depositing it wherever required.

The slope of the cutting has to be suited to the kind of soil which is being cut through. Chalk will stand up almost vertically; but clay is the terror of the railway builder, and has to be left on a very flat slope indeed, or in wet weather the side of the clay cutting will quietly slide down, and deposit itself all over the railway. In very deep cuttings, such as the Roade cutting on the North Western main line, illustrated above, the sides are often held up at a steep angle by brick retaining walls; this keeps down the width of land needed for the railway.

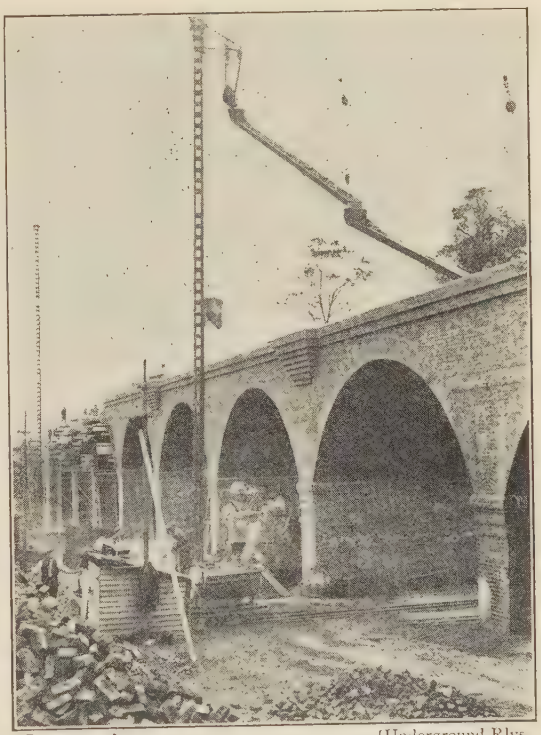
When the cutting becomes too deep to be economical, the engineer must have recourse to tunnelling, but only as a last resort, because tunnelling is always the most costly of all methods of laying a railway. Very often, both in excavating and tunnelling, rock is



By courtesy] BUILDING A BRICK VIADUCT [Underground Rlys.

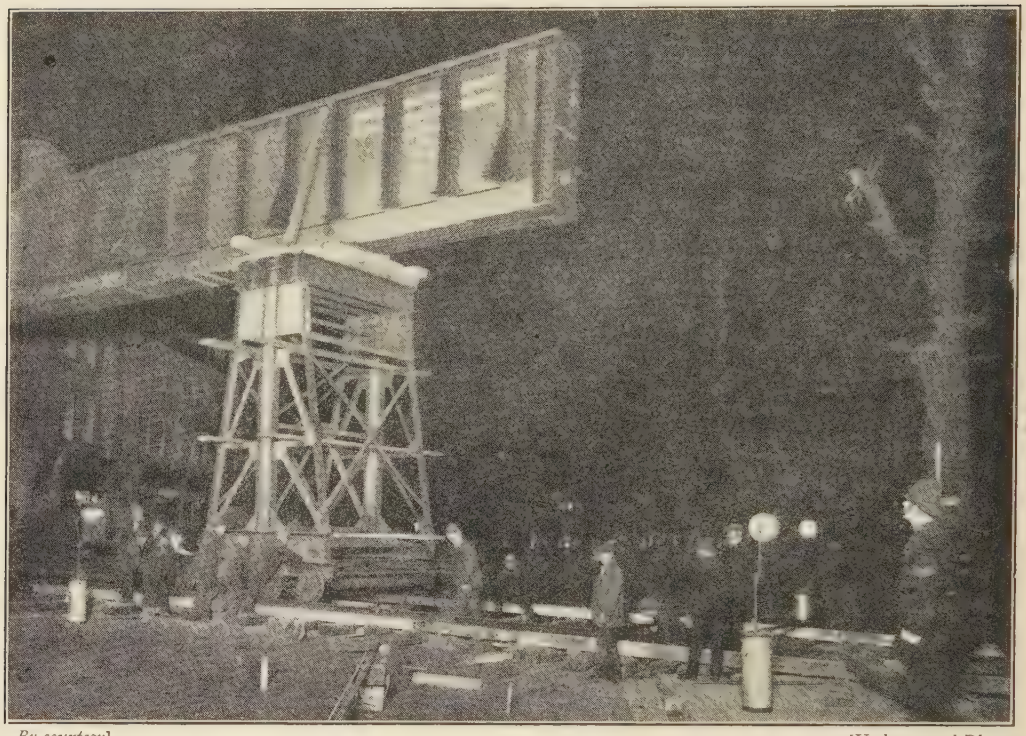
met with, and this means that blasting has to take the place of excavating, which is still more costly. This is more especially the case in mountainous country, where the cost of railway construction per mile goes up by leaps and bounds, owing to the difficulties which have to be surmounted.

Similarly, when the embankment is becoming too high to be reasonable, a bridge with many openings, known as a "viaduct," takes its place. This is especially necessary where a railway crosses a valley subject to flooding in wet weather, in order to provide ample space for the water to pass under the line. Otherwise the water may clear a path for itself by washing



By courtesy] [Underground Rlys.

VIADUCT NEARING COMPLETION



By courtesy] [Underground Rlys.

RUNNING THE GIRDERS ACROSS THE GOLDER'S GREEN ROAD

the line away altogether, as has actually happened on not a few occasions.

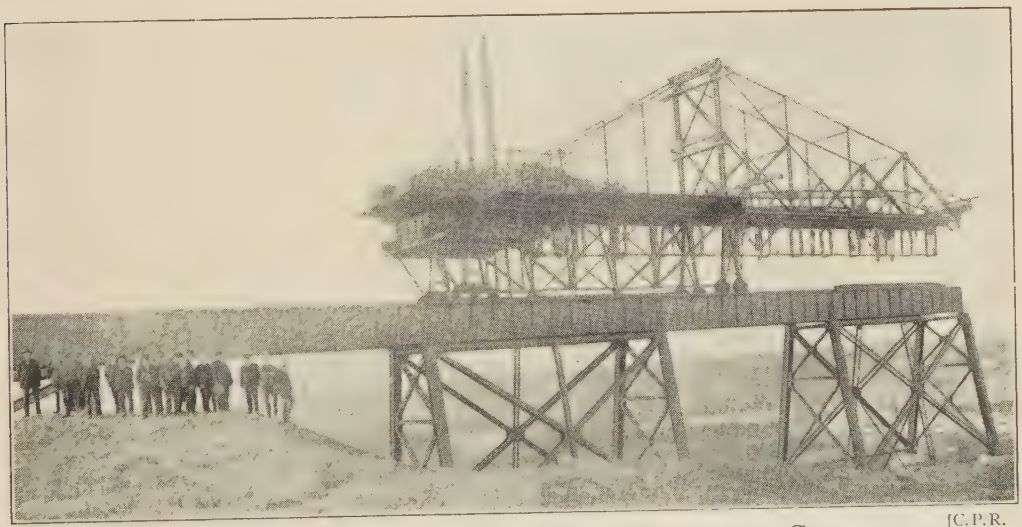
In the pictures on page 51 you see a brick viaduct in course of construction, along the route of the extension of the Hampstead "Tube" to Edgware. Here, of course, it is no longer a tube, but has come out into the open country. In the upper picture you see the wooden framework, or "centring," on which each arch is built; later on, when the brickwork is finished and the cement is dry and solid, the centring is gradually taken away, leaving the arch in position. The lower shows a portion of the completed viaduct; in the foreground is one of the handy towers which take the cement or concrete up in buckets, in a partly liquid state, and distribute it down chutes wherever it is wanted.

Inside the Locomotive Yard Signal-Box, York.

By courtesy] [L.M.S.R.

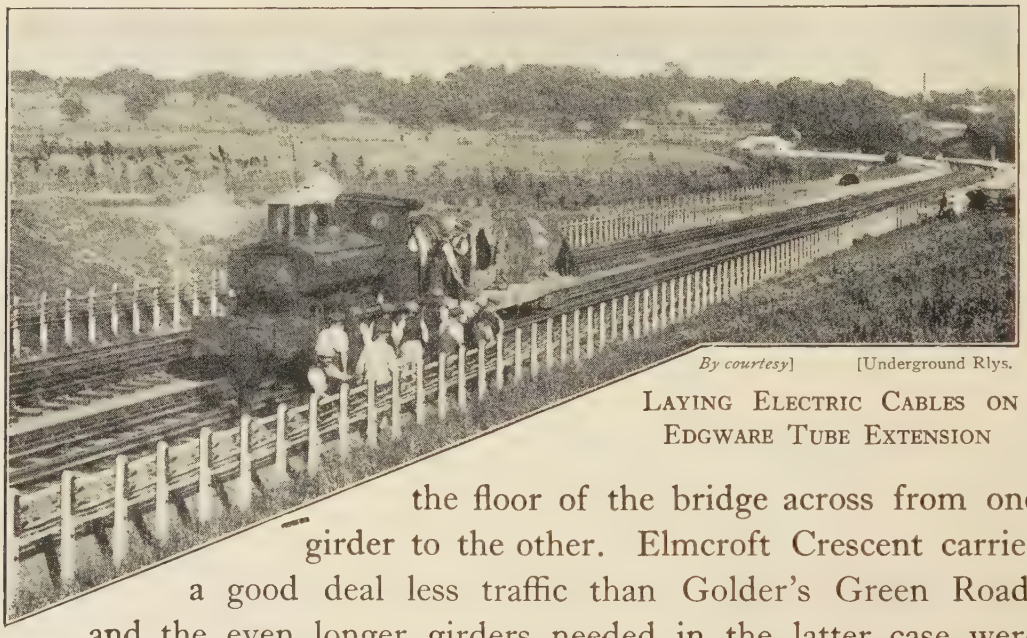
TESTING A GIRDER BRIDGE

The erection of bridges very often provides the engineer with problems almost as acute as those he has solved in making his designs. The striking photograph opposite, for example, illustrates how the girders of the big bridge of the same railway, close to Golder's Green Station, were dealt with. Night-time was chosen, when there was likely to be less traffic passing along the road ; and then, on a temporary railway laid across the road, a trestle carrying one end of the girder was slowly pulled from one side of the road to the other. When the girders had reached their correct position, they were lowered on to their bedplates, and the principal part of the job was complete ; the only operation remaining was to build



By courtesy] [C.P.R.

CONSTRUCTING THE GREAT LETHBRIDGE VIADUCT IN CANADA



By courtesy] [Underground Rlys.

LAYING ELECTRIC CABLES ON EDGWARE TUBE EXTENSION

the floor of the bridge across from one girder to the other. Elmcroft Crescent carries a good deal less traffic than Golder's Green Road, and the even longer girders needed in the latter case were hauled across by wire ropes in daylight, as you can see in the fine picture at the head of this chapter.

As viaducts grow in size, so the difficulties of their construction increase. The vast Lethbridge Viaduct of the Canadian Pacific Railway, of which a picture may be found further on, at page 86, was erected in the way shown on page 53. A large "traveller" was built to run on the railway leading to the bridge, and this contrivance extended far enough outwards to drop the girders of each

By courtesy] LAYING A RAILWAY ACROSS THE CANADIAN PRAIRIES [C.P.R.

span into position, on to the supporting towers, which had been run up from the valley below by its help also. As the viaduct advanced outwards, so the " traveller " advanced with it, until at length the other side of the valley, a mile away, was reached, and the viaduct was complete.

When the cuttings and embankments, tunnels and viaducts, are all finished, the only thing remaining is to lay the track, or, as it is called, the " permanent way." Space would not allow me to go into all its complications, although you can get a good idea as to how it is designed from the picture below, which shows you " switches " and " crossings " of various kinds. In laying lines across the wide-spreading prairies of America, a " track-layer " is employed, as illustrated opposite, rather on the lines of the Lethbridge Viaduct " traveller " ; it is constantly reaching forward, and laying the track ahead of itself, while the engine behind, with its train of rails and wooden sleepers, pushes it gradually along over the line that it has laid.

THE " PERMANENT WAY "

Photo] GANTRY OF SIGNALS AT IPSWICH, L.N.E.R. [F. E. Mackay

SIGNALS AND SIGNALLING

RAILWAY signalling is a very complicated subject; and I must be content to mention just a few of its main principles. First of all, each signal-arm has one side red and the other side white; the red side faces the approaching train to which it refers. As the train is running, too, the driver is only concerned with the signals which point to the left-hand side of the line.

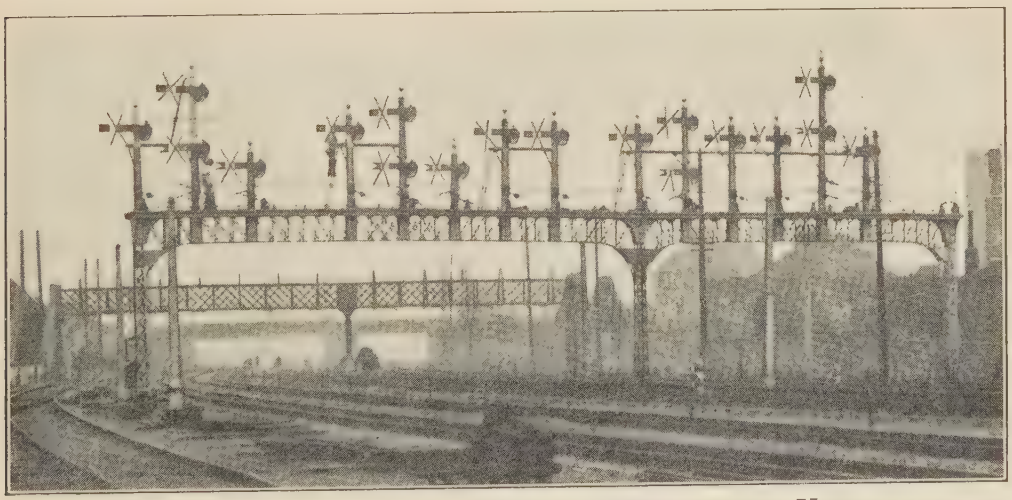
In the picture above, therefore, only three of all the signals carried on the big "gantry" apply to trains running in the direction away from you; all the remainder concern trains coming towards you. Looking again at this photograph, you will notice that the signal-arms for the "away" direction, and four of those governing the "towards you" direction, have little fish-tailed pieces cut out of the ends of the arms.

The fish-tailed arm denotes a "distant" signal; the square-ended arm a "home" signal. When a driver sees a home signal at danger, he must stop; a distant signal at danger tells him that

the next home signal beyond, at a distance of half-a-mile or less away, is also at danger. He does not have to stop his train at a distant signal, when it is " up " ; but it gives him the necessary time and space in which to pull up at the home signal, especially when he is running at high speed.

The whole of each railway route is divided up into sections, or " blocks," each controlled by a signal-box. The principle of the " block " system of signalling is that no two trains shall be in the same section, on the same line of rails, at the same time. Where there are no junctions, there are usually at least three signals to control each of the two directions of running ; first you pass the distant signal, about half-a-mile away from the signal-box ; then the home signal ; and then, about a train's length or so in front of that, a second home signal, called the " starting " signal, or " starter." At a station you will usually find the home signal at one end of the platform, and the starter at the other.

At junctions the array of signals becomes a good deal more complicated, as signals have to be provided to govern every line over which a train can travel. The tallest of these usually refers to

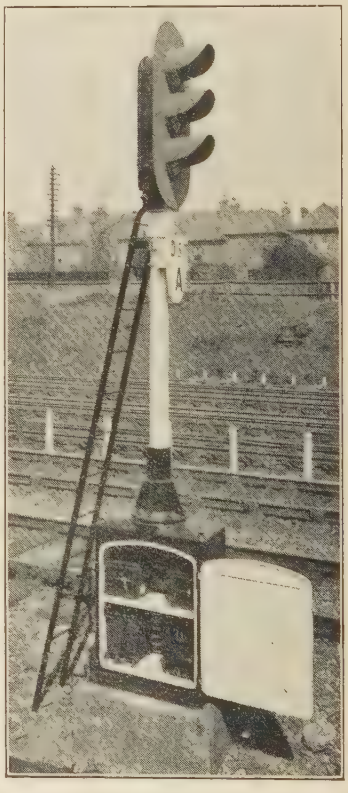


SIGNALS " CROSSED " BEFORE BEING BROUGHT INTO USE

HALL " COLOUR-LIGHT " SIGNAL, L.N.E.R.

the main line, and the remaining posts are " stepped " in height according to the relative importance of the line to which they refer. In the Ipswich signal-gantry at the head of the chapter, the signals are in three groups : the left-hand group governs the up and down Norwich main lines on the extreme left ; the middle group the Yarmouth lines, on which the train is running ; and the right-hand group the goods lines.

Efforts are now made to simplify these masses of signals where possible by the use of one of the " route-indicating " signals shown at the bottom of page 59. In this, which is just outside the Lowestoft terminus of the L.N.E.R., instead of having a separate signal-arm to indicate each platform, the one highest arm alone is used, and in the case below there appears a number, according to the platform for which the line is set.

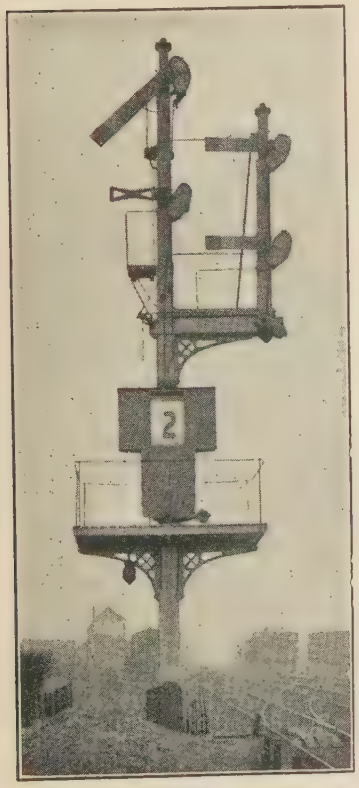


THREE-POSITION " COLOUR-LIGHT " SIGNAL, L.N.E.R.

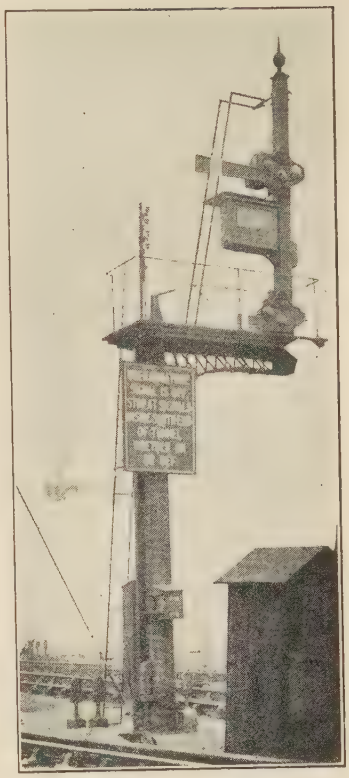
Many other types of signal, which have been designed to serve special purposes, might be mentioned, and you see some of them illustrated. For example, below the signal last mentioned, there is a curious arm in the shape of a cross. This is called a " draw-ahead " signal ; when it is " off," or down, it tells a

driver that he may proceed beyond the home signal, even though the latter is at danger, but only so far as will enable him to shunt, or perform some other necessary duty, without going on into the next section.

The crosses on all the signals on page 57, however, are only temporary; they simply indicate that the gantry is new, and that the signals have not yet been brought into use. If you see a ring on the end of a signal-arm, as on the right-hand side of the picture on page 62, it shows that the signal applies to a goods line, or a line of less importance than the main line. Shunting movements, however, are very largely controlled by "ground-discs," or dwarf signals on the ground, of which you see an example in front of the signal-box at the top of page 61.

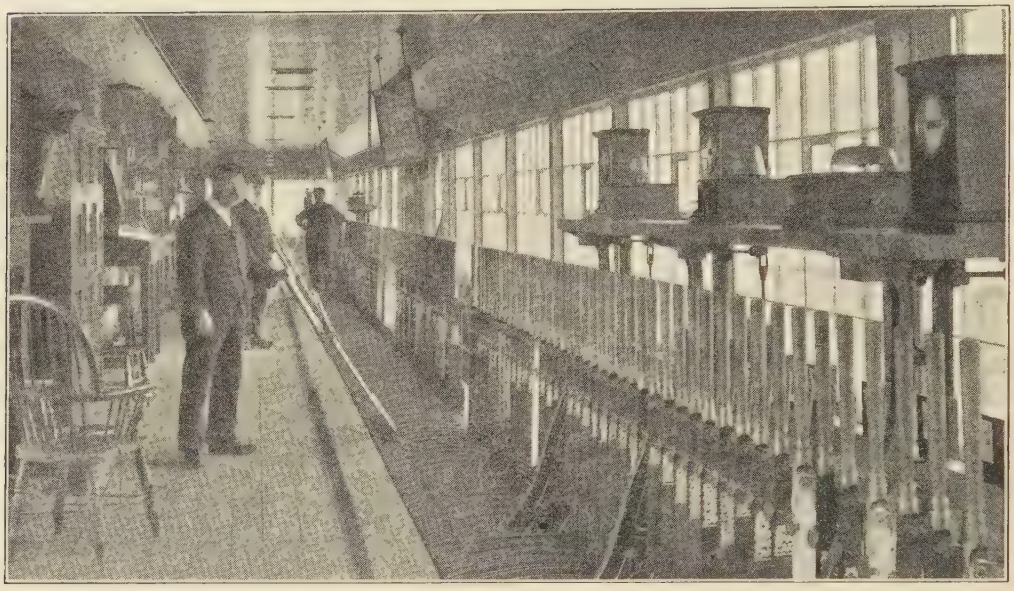


ROUTE-INDICATING SEMAPHORE SIGNAL, L.N.E.R.



THREE-POSITION SEMAPHORE SIGNAL, L.N.E.R.

In these days a beginning is being made in the use of what are called "three-position" signals, which really combine in one both home and distant signals. That shown in the picture above, outside King's Cross terminus on the L.N.E.R., indicates "Danger" in the horizontal position in which you see it; when raised to an angle of 45 degrees, it says "Proceed cautiously; the next home signal is



INTERIOR OF LOCOMOTIVE YARD BOX AT YORK, L.N.E.R.

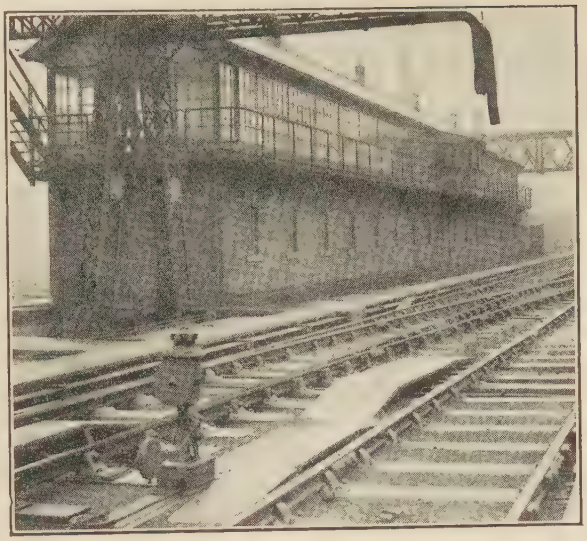
at danger " ; and then it can be raised to a vertical position, parallel to the post, when it shows : " All clear." The three corresponding lights displayed at night are red, green and yellow.

Another variety of the three-position signals is that in which lights only are used, both by day and night, and no signal-arms at all. One of these signals, of which a whole series is now installed between Marylebone terminus and Wembley, on the Great Central section of the L.N.E.R., appears at the bottom of page 58. It is surprising at what a tremendous distance away you can see these hooded lights, even in broad daylight. The signal at the top of the same page is a home signal of the same type.

The biggest signal-box in the country, with no less than 295 levers in one straight line, figures in the photographs on pages 60 and 61. Beneath the great frame in which all the levers are fixed is what is known as the " locking "—that vastly important part of the signalling which sees to it that signals and switches cannot be set in such a way as would allow trains to cross each other's paths and

A Steam Excavator at Work on the Edgware Tube Extension

so collide. The numbers painted on the levers refer to this locking, and the complicated diagram which hangs in the box shows the position of every signal and switch, and the number of the lever that works each one. Every signal-box, large and small, is similarly equipped.



Locomotive Yard Signal-box, York

In many of the largest boxes to-day, electric or electro-pneumatic power is used to work signals and points, in which case little "toy" levers take the place of the big levers shown on page 60, and the work of the signalmen is made much easier. On the shelf behind the levers are seen the "instruments," whereby the movement of the trains is signalled from box to box; the messages are made audible by means of the bells beside them, on which a

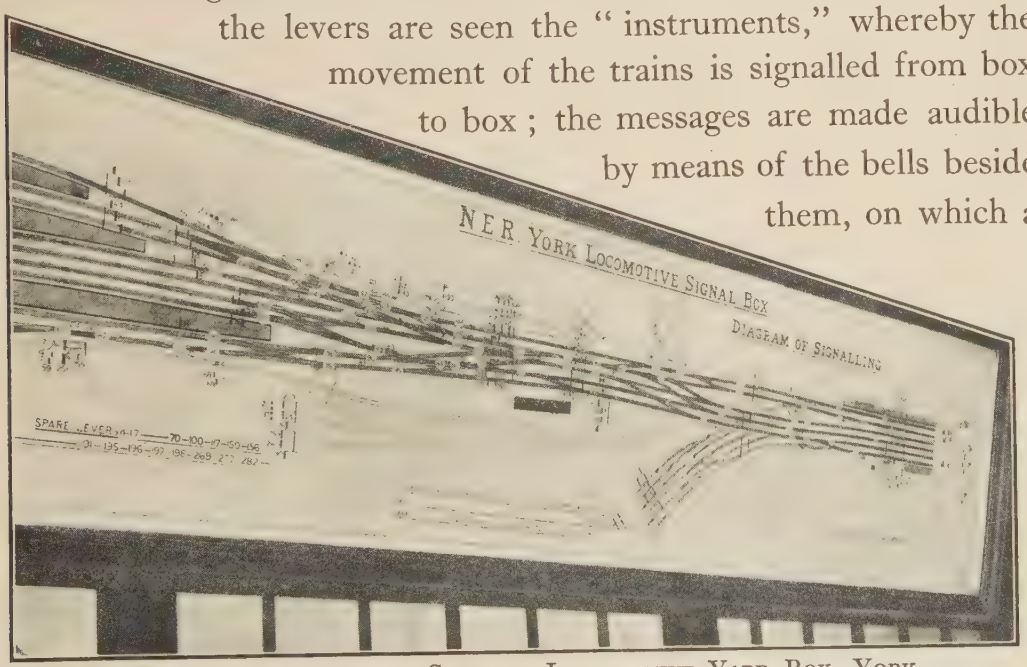
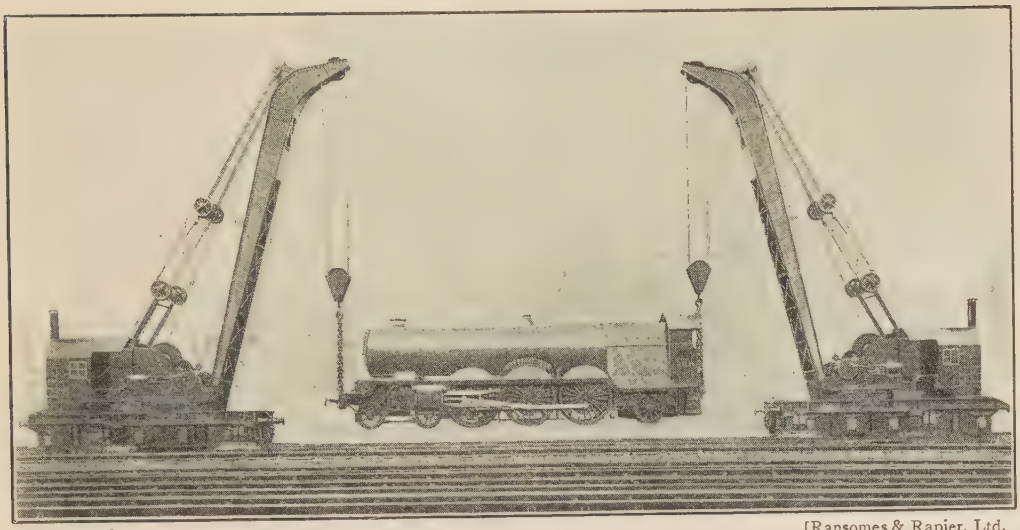


Diagram of Points and Signals, Locomotive Yard Box, York

special code of signals is conducted. Where trains run in both directions over a single line of rails, collisions are avoided by means of the " tablet " system of signalling. Briefly, this means that each driver must be in possession of a special " token," before he is allowed to pass on to the single line. This token can only be obtained from special signalling instruments, electrically controlled, at both ends of the single line section.

The last photograph shows how the taking and giving up of the token are facilitated by the erection of apparatus at the line side. As the engine passes on to the single-line, the fireman puts his arm through the ring at the end of the " staff," seen at the right-hand side of the picture, and neatly hooks it off ; when the engine is coming off the single line, on the other hand, he throws the ring on to the horn sticking up on the middle post, whence it is fetched by the signalman, and returned into the signalling instrument. This return must be made before another train is allowed to run on to the single line.

Apparatus for Single-line Working at Maidenhead, G.W.R.



By courtesy] LIFTING A 98-TON LOCOMOTIVE [Ransomes & Rapier, Ltd.

RAILWAY ACCIDENTS

"ACCIDENTS *will* happen," the proverb tells us, "even in the best-regulated families." Railways are no exception to the rule; and yet it is worth stopping for a moment to reflect on the remarkable pitch of safety to which railway travelling has been brought in this country. The average number of travellers who have lost their lives while making journeys in British trains, over a number of past years, has been only eight a year.

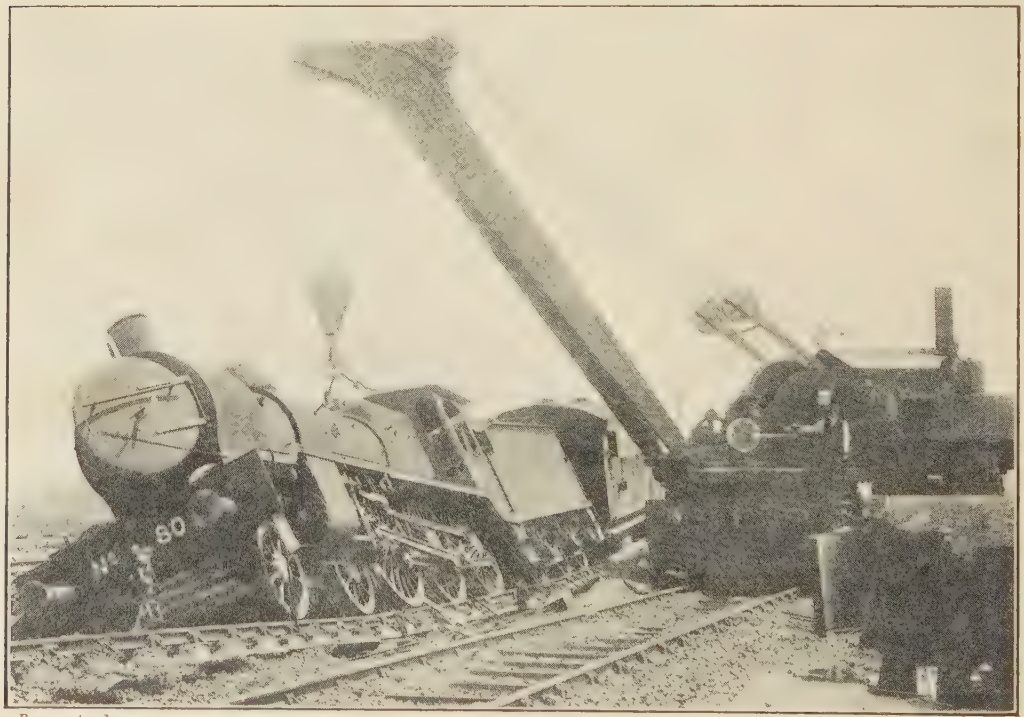
Yet something like 2,500,000,000 railway journeys are made in the British Isles every year. So the chances of being involved in a fatal accident when you step into a British train are not very terrifying —they amount to one chance in about three hundred millions! It has rightly been said that the inside of a British train is one of the safest places to be found the whole world over.

But careful provision has to be made by the railways, all the same, for dealing with accidents. Located at various convenient points on each line are "breakdown gangs," as they are called; their duty is to hasten to the scene of the mishap, and clear the line of the

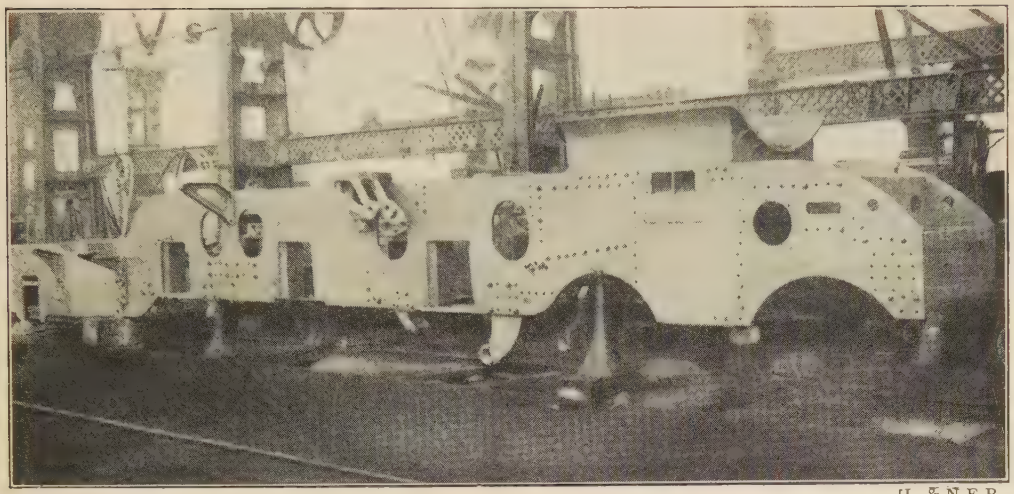
wreckage. Each gang has at its disposal one of the powerful " break-down cranes " shown in these pictures, as well as many other appliances to help in the work of clearance, and to put on the rails again the vehicles which may have left them, if they are not too badly smashed.

The first of all duties, of course, is that of rescuing any people who may still be imprisoned in the wrecked train ; clearing the line in the shortest possible time and at all costs is the next task, in order that the running of the trains over it may be resumed.

Considerable ingenuity is called for in the design of these cranes, which, despite their size and power, must be able to pass under all the bridges and tunnels on the way to the scene of their operations. For this purpose the long arm, or " jib " of the crane is lowered, when running, into a horizontal position, and carried on one or two " guard " trucks ; the crane chimney also is taken down.



By courtesy] THE BREAKDOWN CRANE AT WORK [Ransomes & Rapier, Ltd.



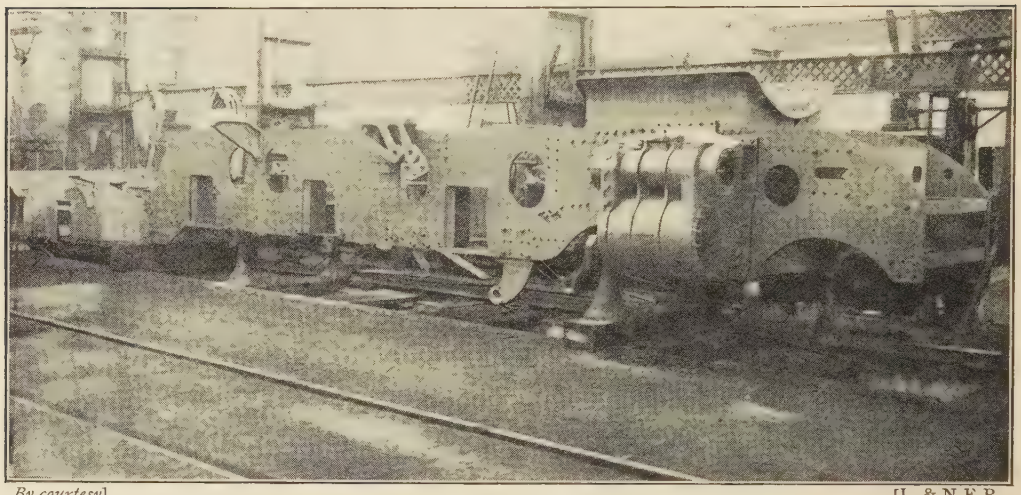
By courtesy] [L. & N.E.R.

BEGINNING TO BUILD A "PACIFIC" EXPRESS LOCOMOTIVE AT DONCASTER
THE MAIN FRAMES IN POSITION

HOW A LOCOMOTIVE IS BUILT

FIRST of all, in building a locomotive the constructors start just as they would in building a house—with the foundation. The foundation of the engine consists of the "main frames." These are two deep steel plates, running the whole length of the engine from the buffers back to the driver's cab, and about one-and-a-quarter inches thick. They run parallel to each other, and throughout their length they are very strongly connected together to form a perfectly rigid framework.

The two ends of the boiler that produces the steam are mounted on this framework; the cylinders that turn the steam into work are bolted to the main frames, and with them all the complicated machinery by which the steam enters and leaves the cylinders; and then the whole of the engine, boiler, cylinders and frames, is dropped on to the wheels. In the photograph above you can clearly see the long frames of the engine, with the necessary spaces cut in them to fit over the axles.



By courtesy] [L. & N.E.R.

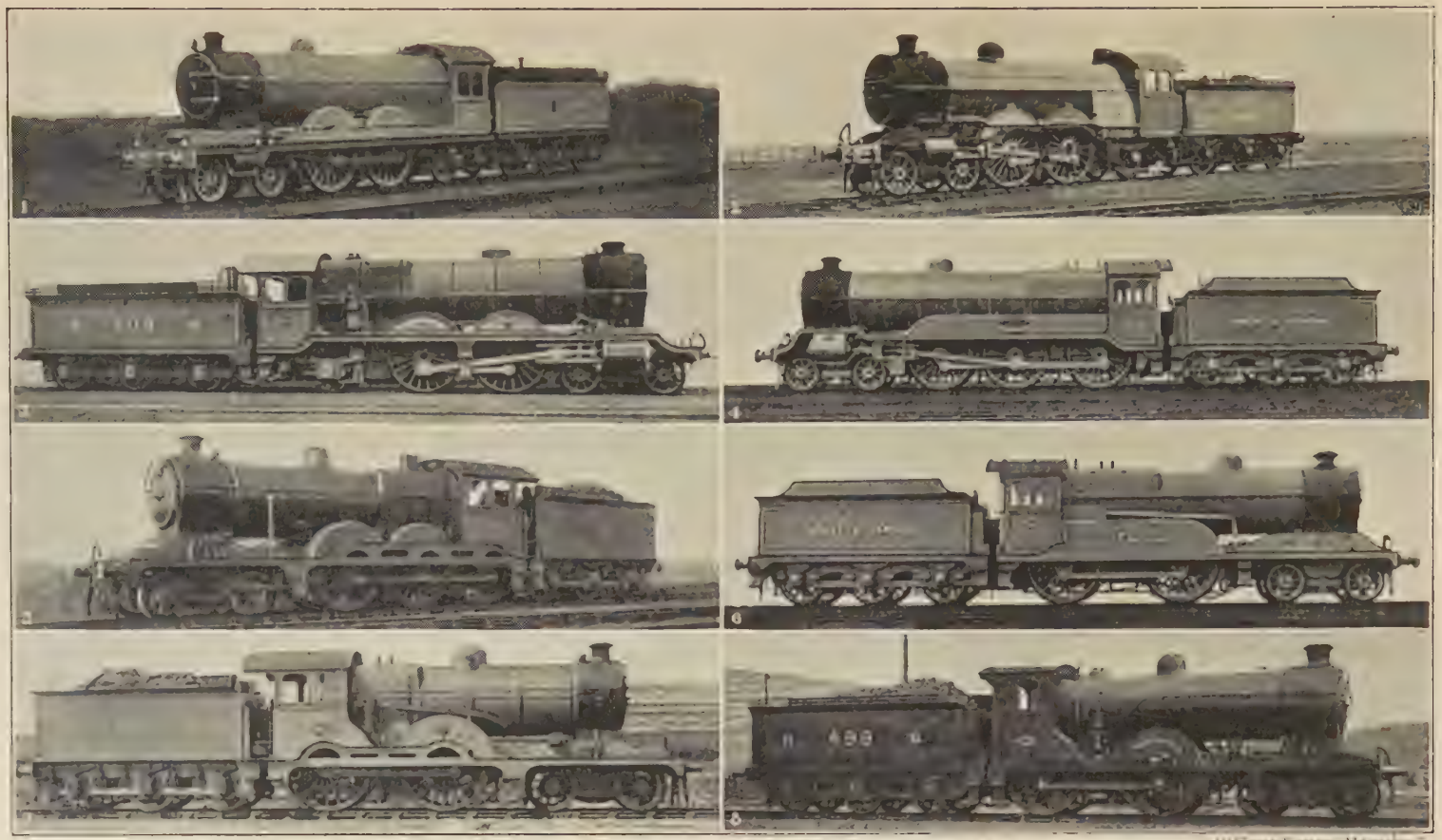
BUILDING A "PACIFIC" ENGINE

OUTSIDE CYLINDER AND PISTON-VALVE CHEST BOLTED TO MAIN FRAMES

Sometimes the cylinders of the engine are arranged outside, where you can see them; sometimes they are inside, between the frames, where they are hidden under the boiler; and when an engine has more than two cylinders, you will find them both inside and outside. The trouble about inside cylinders is that you can only make them up to a certain size, because of the main frames on either side. And although you have a little more room available when the cylinders are outside, even then you are limited to a maximum of 22 inches in diameter. Bigger cylinders than that would hit the platforms and other structures that are often so close up to the line.

This is one of the problems that always cramp the British locomotive engineer so seriously in his designs. Although our wonderful railway pioneers of the early days gave the idea of the railway to the world, yet they did not see far enough ahead. The other countries that copied the idea, and especially America, profited by our experience over here, and left more room round their tracks.

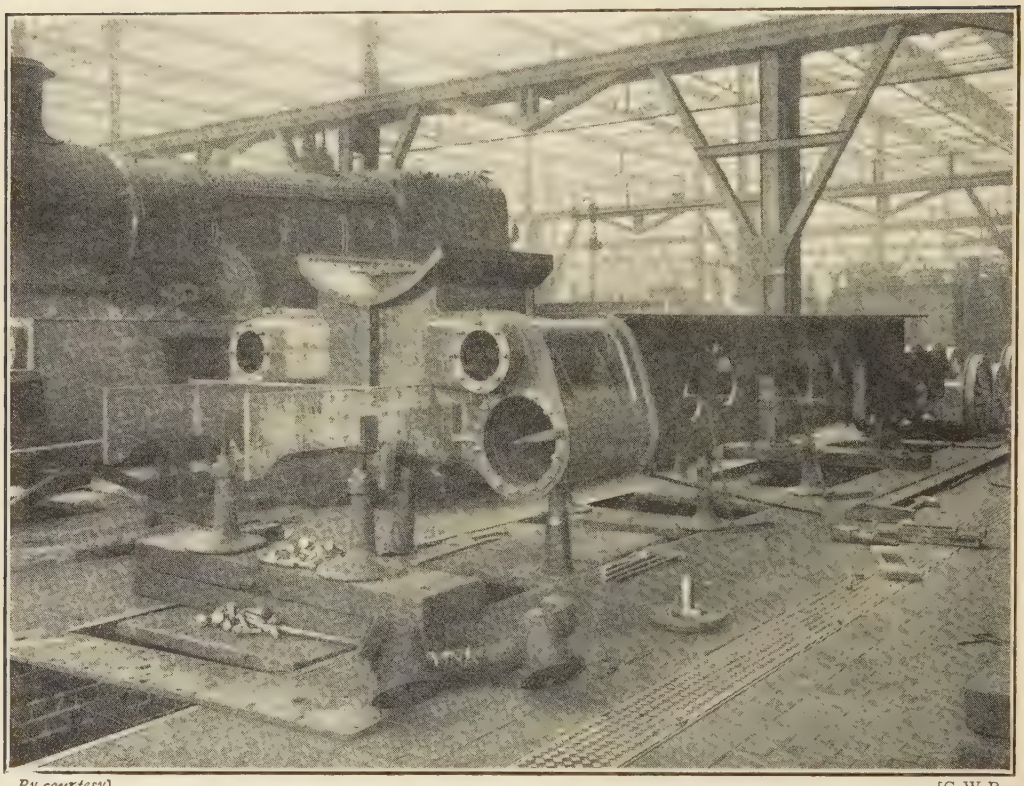
The Americans, although their "gauge" (the distance between



By courtesy] [*"Great Eastern" Magazine*

SOME EXPRESS LOCOMOTIVE TYPES ON THE L. & N.E.R.

1. Three-cylinder "Atlantic" type, North-Eastern Section.
2. Outside 2-cylinder "Atlantic" type, Great Northern Section.
3. Outside 2-cylinder "Atlantic" type, North British Section.
4. Four-cylinder 4-6-0 type, Great Central Section.
5. Inside 2-cylinder 4-6-0 type, Great Eastern Section.
6. Inside 2-cylinder 4-4-0 type, Great Central Section.
7. Inside 2-cylinder 4-4-0 type, Great Eastern Section.
8. Inside 2-cylinder 4-4-0 type, North British Section.



By courtesy] [G.W.R.

BUILDING AN ENGINE AT SWINDON WORKS
MAIN FRAMES, SHOWING CYLINDERS AND SADDLE FOR SMOKE-BOX IN POSITION

the lines) is the same as ours, have at least three feet more room vertically in which to build than we have, and proportionately in width too. So the biggest American locomotives are twice, and more than twice in some cases, the weight and power of the biggest that we can build in this country.

Bigger boilers mean more steam, and bigger cylinders mean a better opportunity of using it up ; bigger boilers and bigger cylinders are therefore necessary if you want more power. So when the British locomotive designer wanted to get more tractive power than he could with a pair of 22-inch cylinders, what did he do ? He simply had recourse to three or four cylinders instead of two.

Three-cylinder " simple " (I will explain the word " simple " in

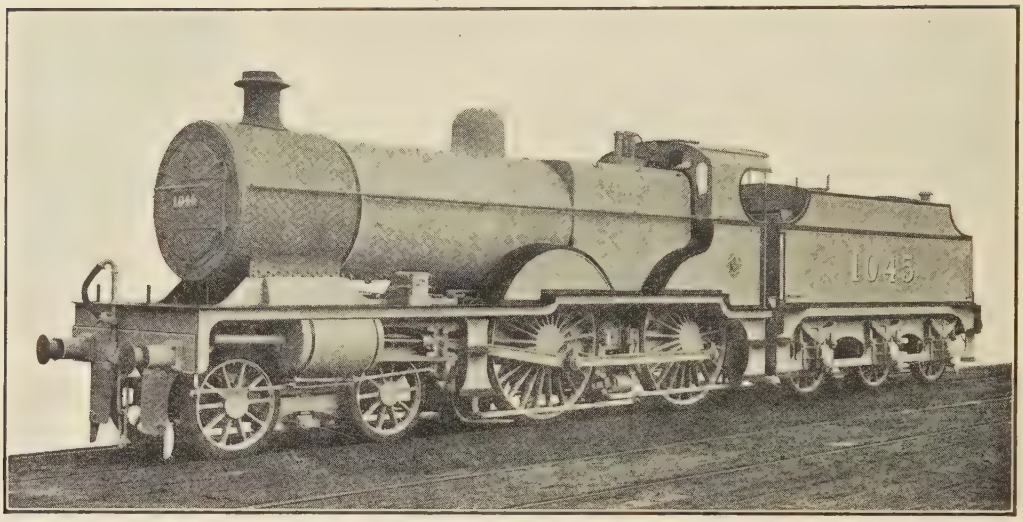
a moment) engines you will find principally on the London and North Eastern Railway ; the famous " Pacific " engine, " Flying Scotsman," of Wembley fame, is a 3-cylinder engine, and the North Eastern section of the same railway has a very large number of three-cylinder types. You can always tell a three-cylinder " simple " engine, because it makes six puffs every time the driving wheels go round, instead of the usual four.

On other railways four cylinders are more popular ; one of the best-known four-cylinder passenger types is the " Castle " class on the Great Western Railway, which was represented at Wembley Exhibition by the well-known " Caerphilly Castle." The " Claughton " class on the late London and North Western, and now L.M.S. Railway, is another favourite four-cylinder express type.

By courtesy] [C.P.R.

EARLY 4-4-0 AND MODERN 4-6-2 CANADIAN ENGINES

Notice how the big right-hand Engine overhangs the track on both sides.



By courtesy] MIDLAND THREE-CYLINDER COMPOUND 4-4-0 ENGINE [L.M.S.

Quite another arrangement of cylinders is that known as "compound." The most extensive series of compound engines in the country is found on the Midland Division of the L.M.S., which will soon have nearly two hundred of them. In these engines the steam is led from the boiler into one large cylinder, known as the "high pressure" cylinder, between the two main frames; and when it has done its work in that, it is led on into the two "low pressure" cylinders, which are outside the frames, in order to do some more. Compound engines are used very extensively on the Continent of Europe, but they are not so popular over here.

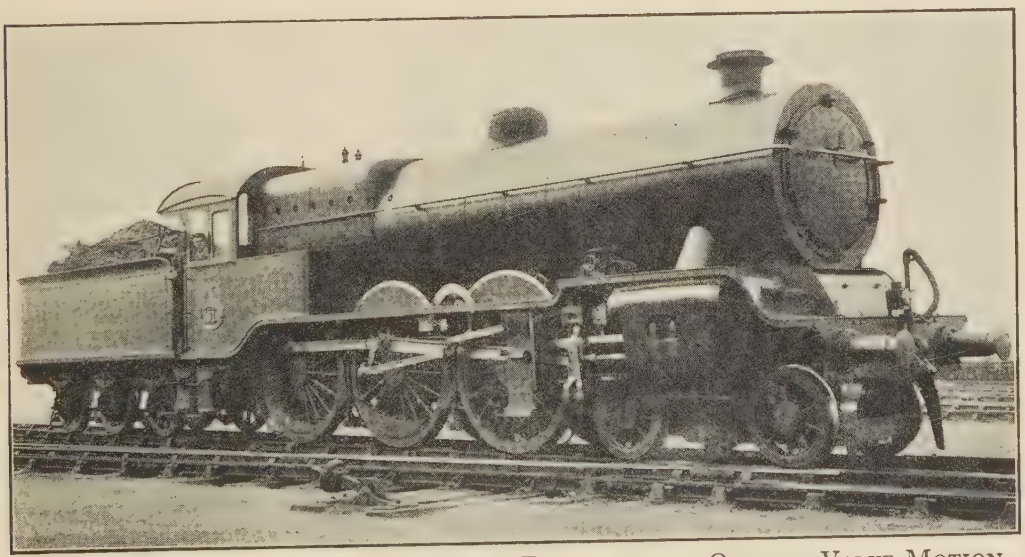
All locomotive engines throw a lot of unused power out of their chimneys; the force with which the "puffs" are ejected does not leave that in much doubt. Steam enters the cylinder at one end, pushes the "piston" forward and so turns the driving wheels round; then that very important mechanism known as the valve-motion suddenly allows steam to enter at the opposite end of the cylinder, driving the piston back again.

But what becomes of the steam already in the cylinder? The same valve-motion sees to it that the opening in the cylinder through

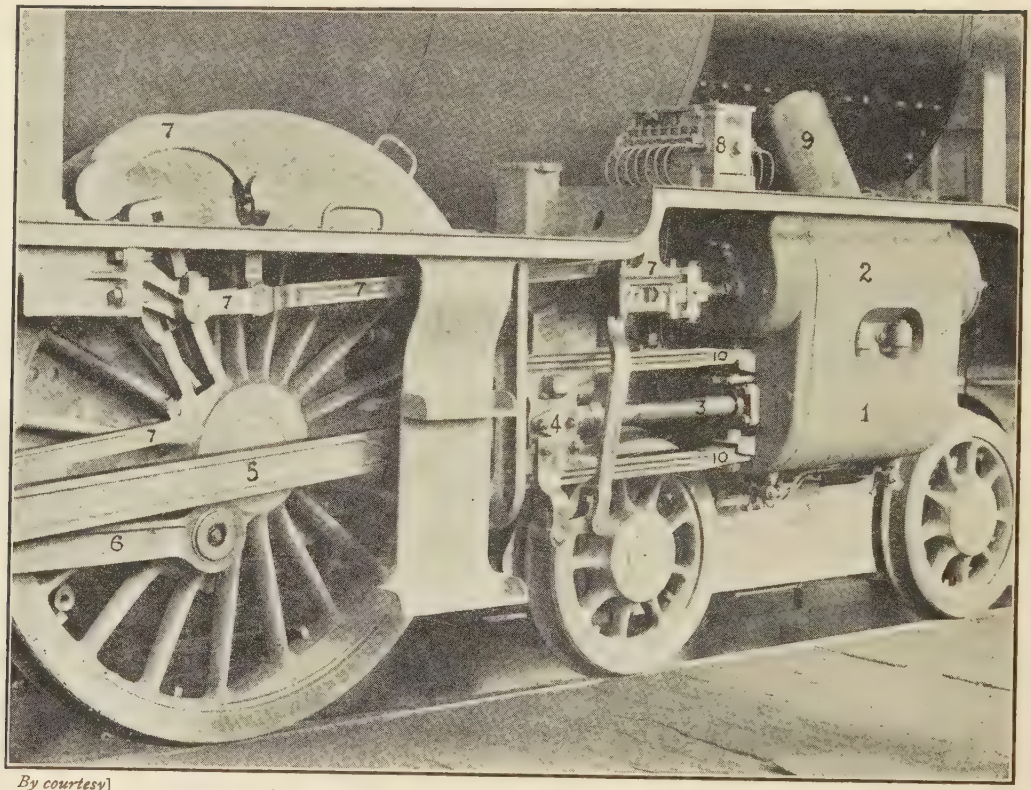
which the steam came in is now connected to a passage which wil lead it out into the chimney. So steam is " pushed " out of both ends of the cylinder in turn every time the driving wheels go round, and with an ordinary two-cylinder engine you get four puffs to every revolution. This steam escaping through the chimney performs another important service, of which more in a moment.

In many modern engines the valve-motion to which I have referred is built outside the engine ; you will see it very clearly in the photograph on the next page. It is generally the custom on the Continent and in America to put all the machinery outside in this way ; it may not be a very pretty practice, but it is much more convenient for the engineers when they want to get at the various parts for inspection or repairs.

You will notice in this photograph the end of the " piston-rod " (numbered " 3 ") coming out of the cylinder (" 1 "), and terminating in the " cross-head " (" 4 "), which slides evenly to and fro between the " slide-bars " (" 10 ") ; the long " connecting-rod " (" 5 ") joining the cross-head to a pin on the driving-wheel, and so changing



L.M.S. Four-cylinder 4-6-0 Express Engine, with Outside Valve-Motion



By courtesy] A Near View of the Valve-motion ["Railway Gazette"

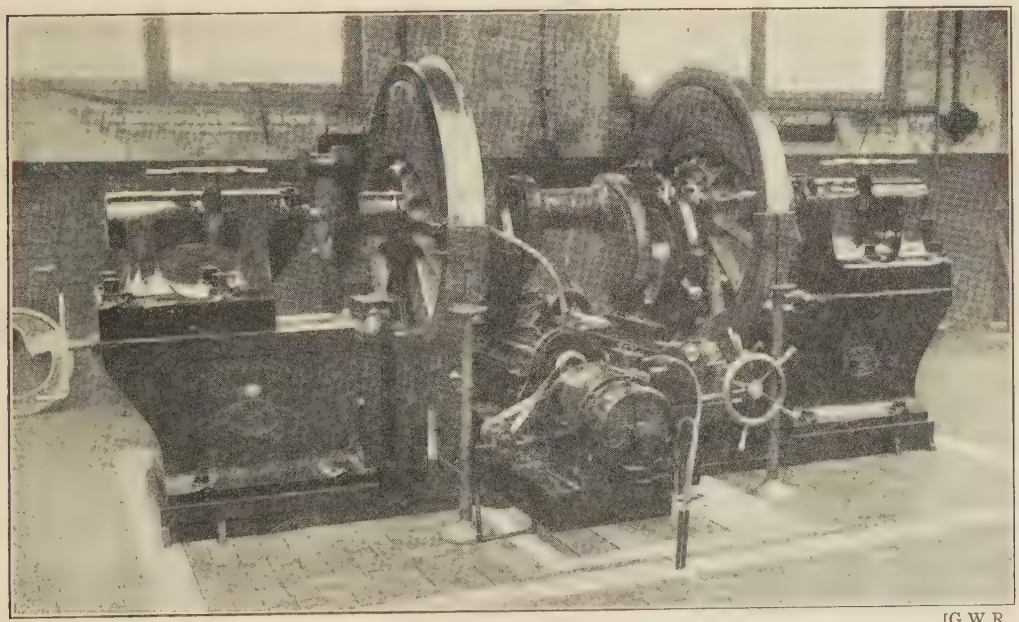
the to-and-fro motion of the piston into the circular motion of the wheel; and, last of all, the "coupling-rod ("6"), which pins the big coupled wheels together, and so increases the grip of the driving-wheels on the rail. Above the cylinder is the "piston-valve" chamber ("2"), where is carried out the important work of admitting the steam into the cylinder, and letting it out again. The motion which operates the valves I have marked "7," and the main steam-pipe from boiler to cylinder is numbered "9." No. "8" is the automatic lubricator for the cylinders, valves and motion.

You will well understand that the flying round of these heavy parts, when the engine is in motion, and especially at very high speeds, would be likely to lead to very unsteady riding unless something were done to counteract these disturbing forces. So the

engine is " balanced " in various ways, the most familiar of which is the balance-weight attached to the rim of the driving wheels. The remarkable machine at Swindon Works of the Great Western Railway, which you see illustrated on this page, is designed to show if this balancing has been properly done.

I well remember once seeing a big pair of driving-wheels spun round on this machine at a speed equivalent to 60 miles an hour; the machine was then stopped, and the weight in one of the balance-weights was altered by two or three pounds. The way in which the " balance " had been disturbed was simply extraordinary; in fact, the wheel concerned began to wobble so violently that the machine had to be stopped long before the full speed was reached.

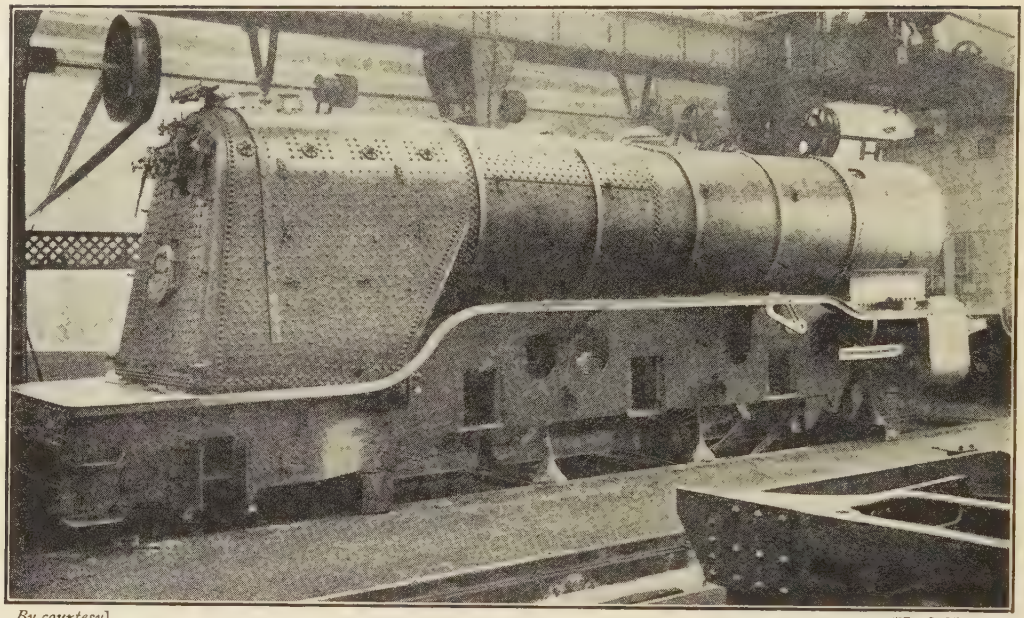
Another matter in connection with both wheels and motion to which very careful attention must be paid is that of lubrication. In big modern engines the oil is forced into the cylinders and valves under pressure, and by ingenious arrangements the driver can see,



By courtesy] [G.W.R

WHEEL-BALANCING MACHINE AT SWINDON WORKS

Notice the pair of driving-wheels in position, and the balance-weights inside the rims.



By courtesy] [L. & N.E.R.

BUILDING A "PACIFIC" ENGINE AT DONCASTER
THE BOILER IN POSITION ON THE FRAMES

while comfortably inside his shelter or "cab," exactly how much oil each part is getting. In olden days he had often to crawl precariously round the front of the engine, while the train was travelling at speed, in order to keep some of these parts properly oiled.

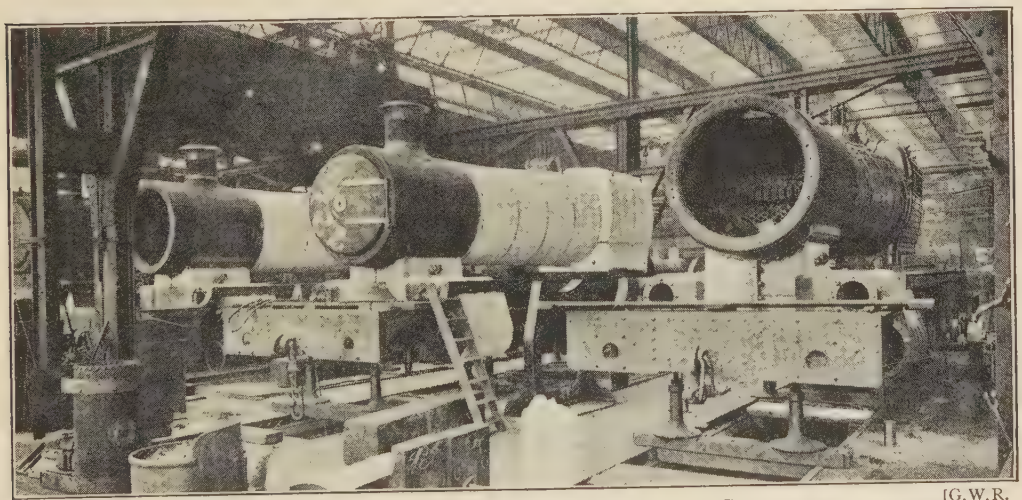
And then the "axle-boxes," which fit into those big spaces in the main frames, and through which the whole weight of the engine comes down on to the wheels, have to be most carefully designed in regard to lubrication, and lined with metal of a special wearing quality; the same applies to all the various parts where metal "rubs" metal. Otherwise, if there is too much friction—such as if small particles of the most harmless-looking grit get into the bearings—the engine will "run hot," and have to be taken off the train.

And now a word or two about steam. You can see more clearly the details of boiler construction in the "undress" locomotive pictures that follow than you can when the engine is all spick and span in its best clothes. For an engine does wear clothes, just as

you do, and for the same reason—in order that it may keep warm. If you touch what appears to you to be the boiler of an ordinary locomotive, you will not burn your hand. This is because, under the beautifully-painted outside covering of the boiler, and between it and the real boiler, a layer is interposed of asbestos, or some other material which will not " conduct " heat readily. This you see clearly in the picture on this page. So the boiler is kept from wasting heat by what is called " radiation," and, incidentally, the paint-work of the engine is protected.

Now, if you look at the big Great Western boiler shown on page 76, you will see that it is in two parts. At the back is the " fire-box," as it is called ; from there to the front you have the " barrel." The barrel is designed to join at the front end on to the " smoke-box," which is that part of the engine immediately under the chimney. It is the smoke-box and fire-box that rest on the main frames of the engine ; between them they carry the barrel.

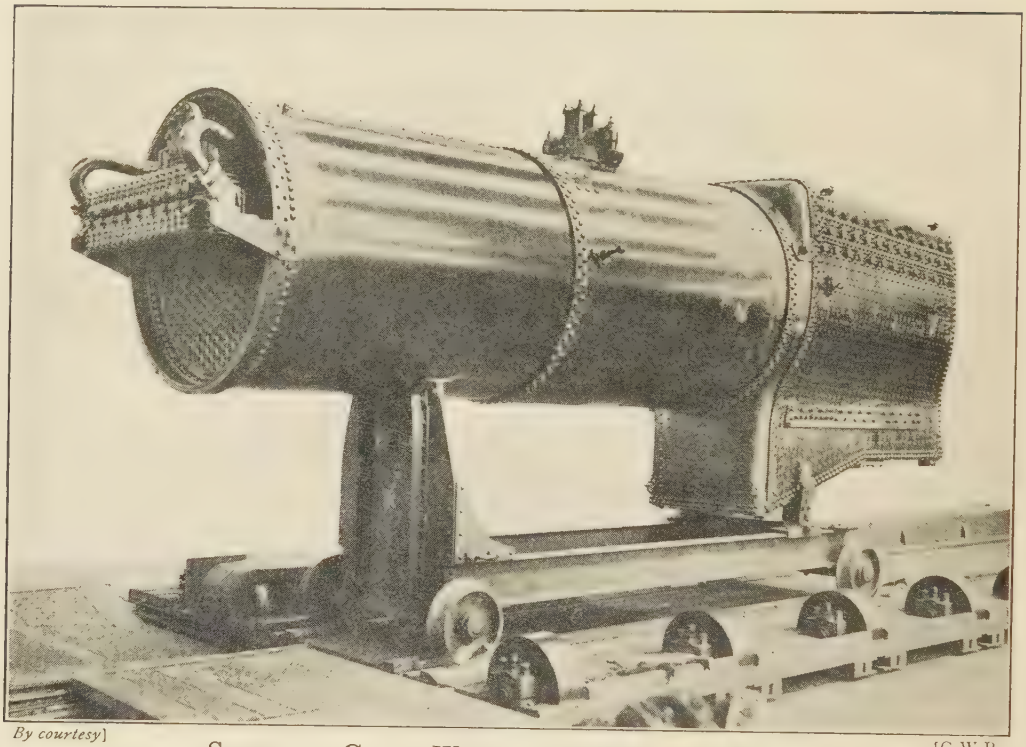
Inside the fire-box, if you could see it, is another and smaller " box " which actually contains the fire ; this inner fire-box and the



[By courtesy] [G.W.R.

ENGINES IN THEIR " WHITE JACKETS " AT SWINDON

The two Engines on the left have been fitted with their asbestos " clothing " round the boiler-barrel, fire-box, cylinders, etc. ; the Engine on the right is waiting to be " dressed."



By courtesy] [G.W.R.

STANDARD GREAT WESTERN LOCOMOTIVE BOILER

Showing fire-box, barrel, safety-valve, front tube-plate and superheater header.

smoke-box are both shut off from the barrel by strong partitions, known as " tube-plates." You see the front tube-plate in the picture of the Great Western boiler ; and this gives you also a useful clue as to the way in which the boiler is constructed. A modern " inner " fire-box is illustrated on the opposite page.

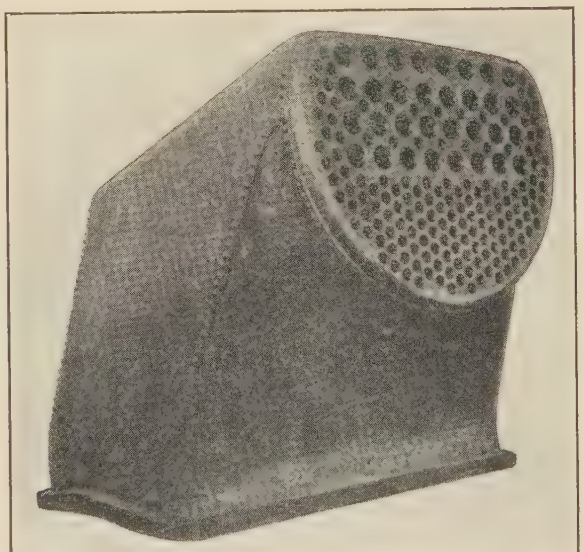
You must remember, first of all, that the locomotive boiler has to produce steam at a faster rate than any other kind of boiler there is. To produce steam fast means to burn coal fast, and to burn coal fast means plenty of draught. The draught for your kitchen fire at home is obtained by having a chimney as high as the house ; but this is clearly impossible on the locomotive, where we have only a total of just over 13 feet in height in which to build. This is where comes in the value of the escaping steam from the cylinders, to

which I referred previously. It is a principle which was discovered long ago by the famous engineer, George Stephenson, and which was embodied in his engine, the " Rocket," as early as 1829.

The steam, as it escapes from the cylinders, is carried into a vertical pipe in the smoke-box (called the " blast-pipe "), which narrows from the bottom to the top. The effect of this narrowing is to make the steam escape from the blast-pipe with great violence ; and as the steam spreads out and fills the chimney, it creates a very strong suction. Air must be sucked from somewhere to fill the vacuum ; and so it comes from under the fire-box, through the ash-pan and through the fire-grate, on which the fireman is all the time shooting his shovelsful of coal.

This strong draught enables the coal to burn rapidly and fiercely ; and the heat so produced is then drawn through all those myriads of boiler-tubes from the back end of the barrel to the front, and so out into the smoke-box. This explains why you see sparks and black smoke coming out of the locomotive chimney, as well as the partially-condensed steam.

Now the barrel itself, as well as the space between the inner and outer fire-boxes, is filled with water. Naturally, the most steam is generated round the inner fire-box, where the fire is actually burning ; but steam is also being produced round every one of those two or three hundred small tubes, which are filled with heat and surrounded with water.

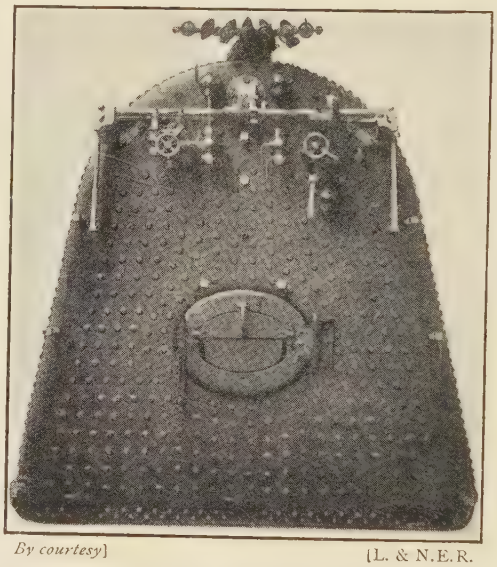


By courtesy [L. & N.E.R.

THE INNER FIRE-BOX OF A " PACIFIC " ENGINE
Showing fire-box tube-plate.

The fiercer the blast of the escaping steam is, so much the stronger the draught, and so much the more rapidly can steam be produced if required. So the locomotive is able to adapt itself readily to very hard work, when necessary, or to steam more easily, when the load is lighter or the speed desired is not so high.

You will also see, on the front of that Great Western boiler, a curious collection of pipes, which seem to run in all directions from the box, or cham- ber, that is fixed across the upper part of the barrel. This chamber, which is called a "header," forms part of the "superheater," with which every modern engine is equipped.



By courtesy [L. & N.E.R.

FIREBOX OF "PACIFIC" ENGINE, CAB SIDE

Notice myriads of stay-bolts securing outer to inner fire-box; also regulator handle and fire-hole door.

The boiler is never kept quite full of water up to the top, as space must be left in which the steam may "col- lect." On the top of most loco- motive boilers you will see an arrangement near the centre, rather like a bowler hat in shape, and known as the "dome." This covers a chamber open- ing out of the boiler, in which works the regulator—that is, the appliance, under the driver's control, whereby the steam is allowed to pass from the boiler down to the cylinders. On the Great Western Railway, however, the boiler is always tapered outwards on top in the shape of a cone, in order to make more space for the steam, which is collected in the high front corner of the fire-box, where the Great Western regulator works.

When the driver opens his regulator, the steam rushes along the

main steam-pipe into the superheater " header "—the chamber fixed on the front of the boiler barrel. Between this header and the fire-box, running right through the boiler barrel, there are arranged a number of " flue-tubes," to the tune of about a couple of dozen or so, like the ordinary boiler tubes, but much larger.

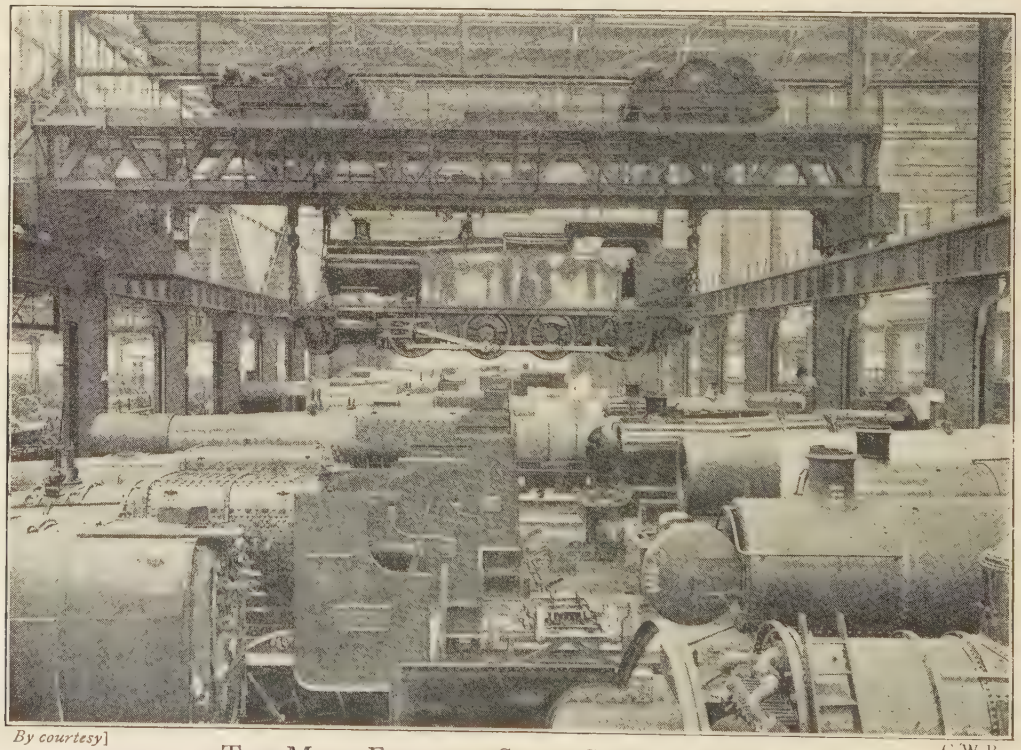
Into these flues are led the array of little steam-pipes coming out of the header, and as these steam-pipes are doubled backwards and forwards inside the flues several times, the steam is all the time getting hotter and hotter—that is, getting superheated—as it hurries through them. Then, in this superheated condition, it is passed on without delay into the cylinders, in order to do its work there. I will not weary you by explaining the technical reasons why superheating the steam is so valuable ; briefly, it tends to make the engine use less coal and water, as well as to pull better ; that is to say, more value is got out of the steam produced in the boiler.

The third of the fittings generally seen on top of a locomotive fulfils a very important duty. On the Great Western boiler it takes the place in the middle of the barrel usually occupied by the steam-dome ; its more usual position is above the fire-box, close to the driver's cab. I refer to the safety-valves. A boiler is designed to take a certain pressure, which, although a wide margin of safety is always left below the pressure that would burst the boiler, must not be exceeded. The safety-valves guarantee that it shall not be exceeded, because they begin to let the steam escape immediately the right figure is passed.

I need not remind you how important this is ; when the engine is standing, or when steam is shut off during running, the increasing pressure of steam in the boiler has no means of escape other than these safety-valves. The safety-valves which are being used on all the latest types of engine are of the Ross " pop " type—

rightly named because of the suddenness with which they begin to blow off, and also with which they shut down again.

Amongst the other external details of the engine, you will notice the coverings to the upper part of the driving wheels, usually known as "splashers." In American engines splashers are unknown, because the "running-plate" along which the driver walks (or along which he is able to walk, if he has any occasion to do so) from the cab towards the front of the engine is raised high up, clear of the wheels altogether. In modern British engines, also, the habit of raising the running-plate high over the wheels is getting common; it is because so much of the motion is being arranged outside the engine nowadays, and these high running-plates make it readily accessible for inspection and attention when required.



By courtesy] G.W.R.

THE MAIN ERECTING SHOP, SWINDON WORKS

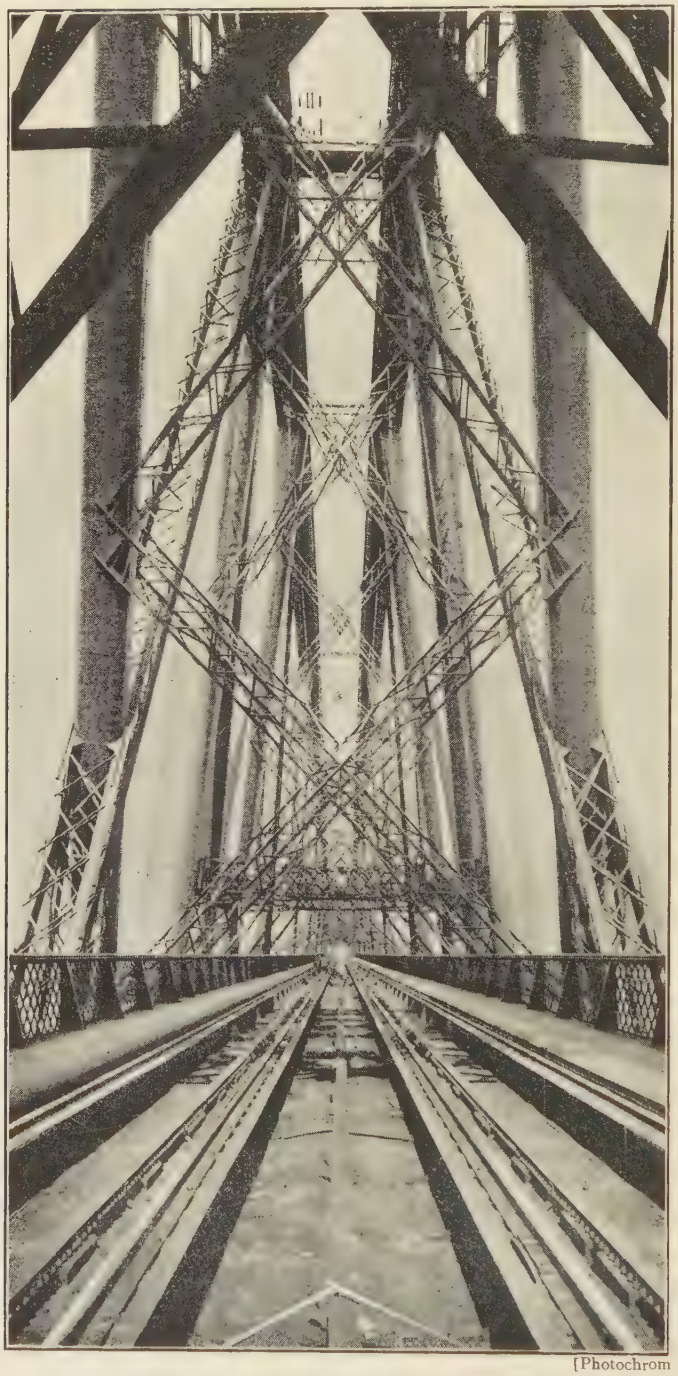
One of the overhead cranes is lifting a 90-ton locomotive.

THE FORTH BRIDGE [Photochrom

WONDERFUL RAILWAY BRIDGES

OF all the remarkable railway structures in the British Isles, the Forth Bridge, although completed away back in 1891, still holds its head high amongst the railway wonders of the world. Prior to its construction passengers and merchandise had to be ferried across the wide-spreading Firth of Forth, from Granton, near Edinburgh, to Burntisland ; while the shortest way round by railway was to make an enormous detour inland to Stirling. So the bold project was formed of bridging the Forth by a cantilever structure no less than one-and-a-half miles long.

The history of its building, which occupied seven years, would take more space than could be spared for its telling ; 54,000 tons of steelwork, held together by 6,500,000 rivets, were swallowed up in the construction. The highest point of the great towers is 361 feet above the water-level, or higher than the topmost point of St. Paul's Cathedral ; the clear height of the bridge above the water in the centre of the vast spans is 157 feet, or more than sufficient to clear the masts of the biggest vessels passing underneath ; and the



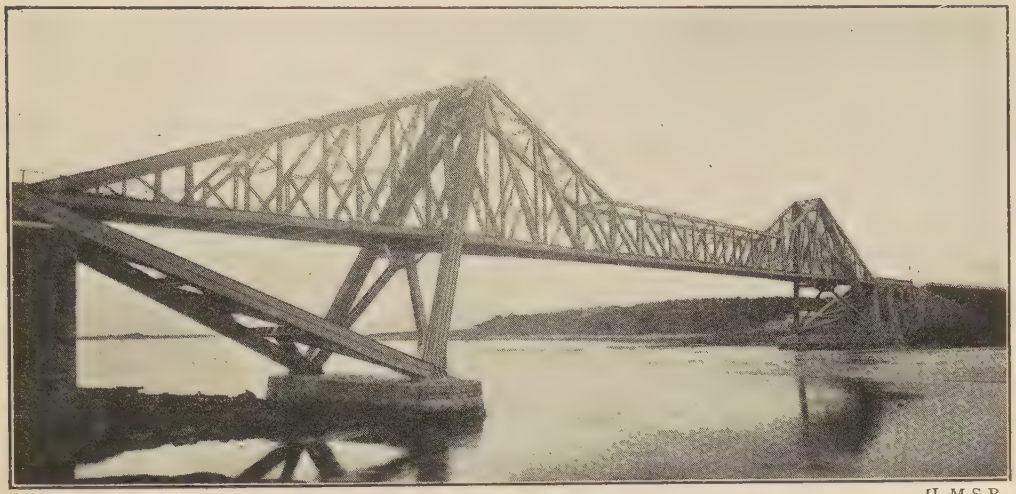
[Photochrom

LOOKING THROUGH THE FORTH BRIDGE

width of each span is no less than 1710 feet —one-third of a mile! The three cantilever towers, stretching out their giant arms to meet each other, measure together exactly one mile over-all.

The bridge has to be painted every three years, as do all our steel structures—especially when near the sea —to prevent the steel corroding away; swarming all over the steelwork, the gang of painters constantly employed on the bridge paint every scrap of it, the job taking them just three years to complete; and then they walk straight back over the bridge, and start painting again where they started before!

The Forth Bridge and its northern neighbour—the Tay Bridge,

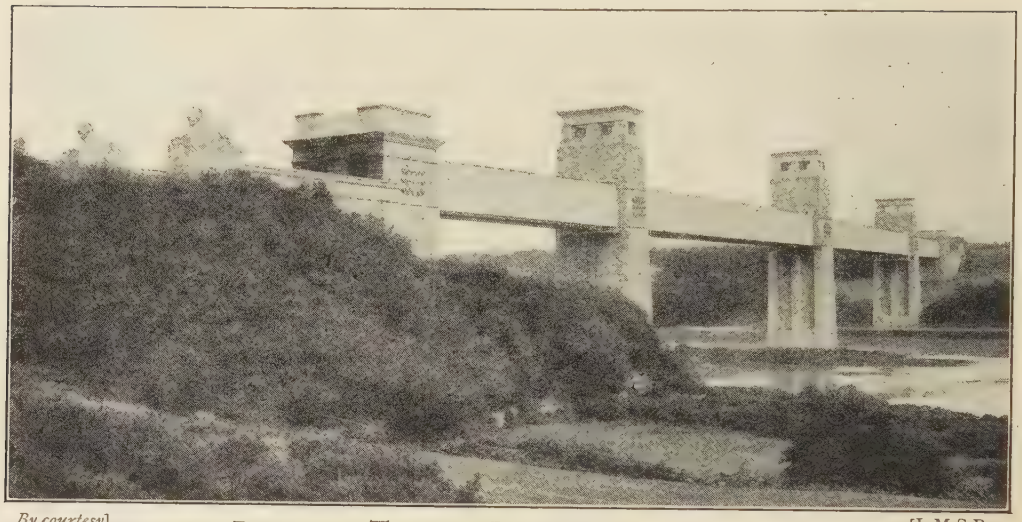


By courtesy] CONNEL FERRY BRIDGE [L.M.S.R.

which is yet longer but was less difficult to construct, as the Tay is much shallower than the Forth—have between them been the making of the East Coast Route, which is now the shortest from London to all points up the East Coast of Scotland. It was this prospect that made it worth while to spend the enormous sum of three million pounds sterling in bridging the Forth.

Above you will see a photograph of Connel Ferry Bridge, in the West Highlands of Scotland. This also bridges an arm of the sea,

By courtesy] SALTASH BRIDGE [G.W.R.



By courtesy] BRITANNIA TUBULAR BRIDGE, FROM ANGLESEY [L.M.S.R.

known as Loch Etive, and is distinguished by the originality of its design ; the main single span is 500 feet from one side to the other.

At the bottom of the same page is the Saltash Bridge of the Great Western Railway, whereby the famous engineer, Brunel, carried his main line from Devonshire into Cornwall across the natural obstacle presented by the River Tamar, 1100 feet wide and 80 feet deep. The design of this bridge is unique ; the floor on which the railway is laid is hung by tie-rods from the great curved booms above, which are made of wrought-iron plates bent round into something like the shape of an egg, or an " elliptical section," as it is called.

This was Brunel's last great work, and at the time of its opening he had to be carried on to the bridge, practically on his death-bed, to see his creation in being. To his credit be it said that, although opened for traffic in 1859, the Saltash bridge is still carrying the vastly heavier locomotives and rolling stock of to-day. The two main spans are 110 feet above the water, and each measures 455 feet in length and weighs 1060 tons.

On these two pages are shown illustrations of the equally famous

East Coast Express Crossing the Forth Bridge.
From photo by The Photochrom Co.

Britannia Tubular Bridge, designed by Robert Stephenson, and opened in 1850. This, again, is a very unusual structure, the only other bridge like it being the neighbouring one over the River Conway. The Britannia Tubular Bridge provides the way whereby the Holyhead main line of the L.M.S. Railway swings across the Menai Straits from North Wales into the island of Anglesey. It consists of two oblong rectangular wrought-iron tubes, each 1510 feet long and weighing 4680 tons, set up on edge side by side, and supported both at the ends and on three central piers. The down trains run through one tube, and the up trains through the other.

One problem which confronted the designer was the effect of heat on two continuous iron tubes of so tremendous a length, between a cold night and a hot day ; in hot weather each tube stretches as much as six inches lengthwise, owing to the incurable tendency of metals to expand as a result of heating. In big bridges, this expansion is always taken up by supporting one end of the bridge on roller bearings, or allowing it freedom to move or slide as it requires ; otherwise there would be very serious trouble, probably

By courtesy] LOOKING THROUGH THE TUBULAR BRIDGE [L.M.S.R.

By courtesy] LETHBRIDGE VIADUCT, ALBERTA [C.P.R.

ending by the bridge buckling out of shape. It is for the same reason that the little gaps are left between the ends of the rails in the track—to allow for expansion.

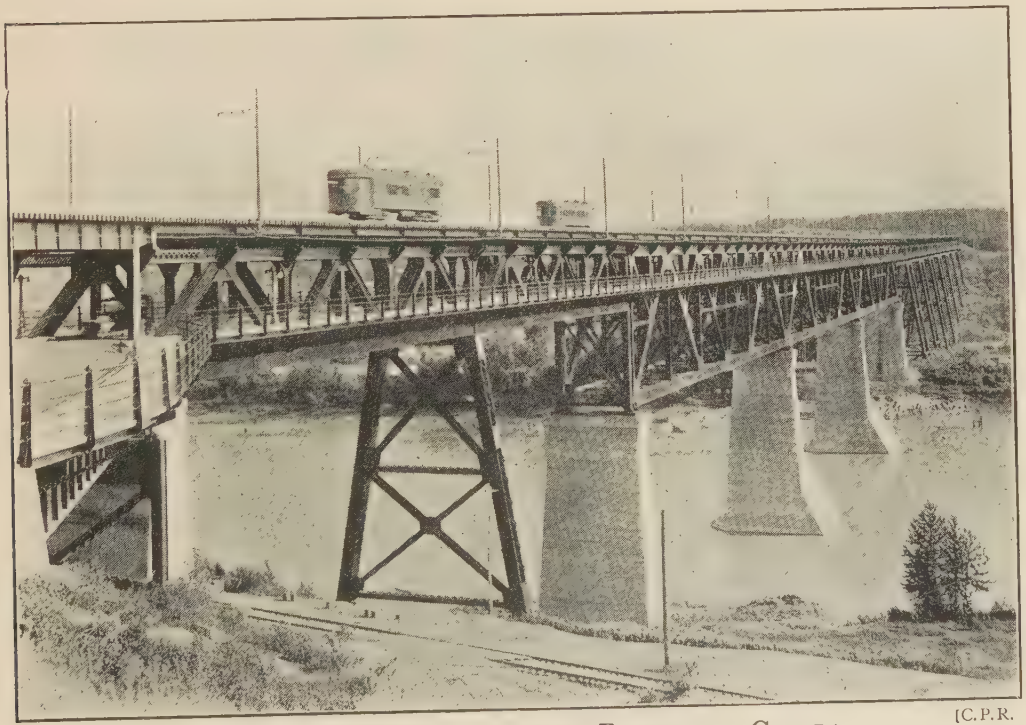
Many other big railway bridges in this country might be mentioned, did space permit ; and the world is full of similar examples of the way in which obstacles put in the way of the railway builders by Nature have been overcome. On this page you see the great Lethbridge Viaduct of the Canadian Pacific Railway, and cannot fail to be struck with the engineering skill which permits of so apparently spidery a structure being made strong enough to carry the 300-ton locomotives and 800-ton trains of modern Canada. This viaduct is just a mile long, and at its highest point is 314 feet above the Belly River ; 12,000 tons of steelwork were used in its construction.

The photograph on page 87 provides an interesting example of the way in which one bridge may be used to serve a number of purposes. This viaduct at Edmonton, Canada, has two " decks " ;

the upper deck carries the main line of the Canadian Pacific Railway, flanked on both sides by electric tramways serving outlying parts of the city ; and then the lower deck is occupied by a wide road.

In the last illustration is seen one of the largest bridges in the world, crossing the wide River St. Lawrence just above the city of Quebec, in Canada. This bridge has had a tragic history. The first design was made and approved in 1901 ; and erection of one of the great cantilever towers had been six years on its way when suddenly, without any warning, the whole 17,000 tons of steel collapsed and fell into the river. Three years of delay occurred while a new and more massive design was under preparation ; but this was at last completed, and the two diamond-shaped towers on both sides of the river, commenced in 1910, were built and finished in 1916.

The only thing remaining was then to build into position the big

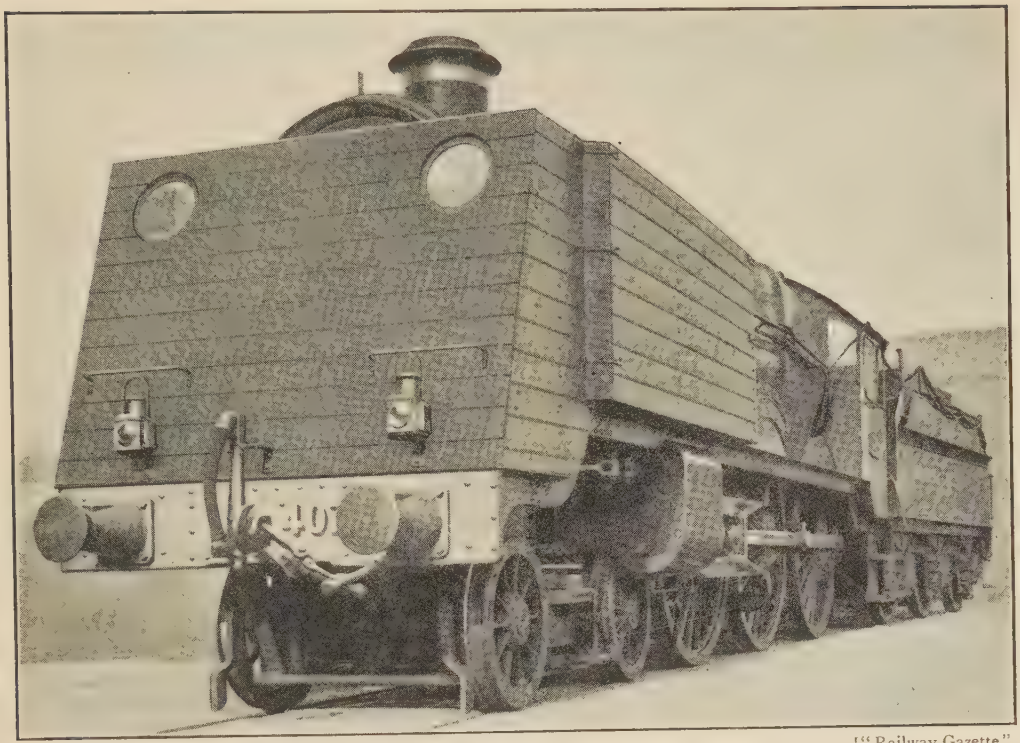


By courtesy] A "DOUBLE-DECK" BRIDGE AT EDMONTON, CANADA [C.P.R.

640-feet girder span of the bridge, whose weight of 5100 tons the cantilevers carry between them. This span was erected at a convenient point near by, and then, with the most careful preparation, it was floated downstream on barges to the site of the bridge, and a beginning was made to hoist it into position. Once again, with absolutely no warning, something gave way, and the whole of this vast mass of metal also fell into the river, a crumpled wreck.

An entirely new span had to be built, and at last, at the end of 1917, this enormously costly bridge was completed and opened. The big main span of 1800 feet just beats in length the spans of our Forth Bridge, and no less than 66,480 tons of steel were swallowed up in the construction.

By courtesy] THE GREAT QUEBEC BRIDGE [C.N.R.



By courtesy] INDICATING SHELTER ON "CALDICOT CASTLE" ["Railway Gazette"

HOW ENGINES ARE TESTED

WHEN a railway has turned out a new type of engine, an early experience the first locomotive of the class has usually to undergo is a very thorough series of tests. The boiler has been tested under its full working pressure of steam, and something over, before it was mounted on the engine frame at the locomotive works. Then, when the engine is at last complete, there comes its first test under steam; and this consists in taking it for a twenty-mile spin, or thereabouts, down the line from the works and back again.

The "trial trip" is made with workmen hanging on all round, as you can see in the picture on page 90; they are armed with large oilcans, and charged with seeing that no part of the machinery

By courtesy] ["Railway Gazette"

"CALDICOT CASTLE" READY FOR THE TESTS

"runs hot," or develops any other kind of trouble. It is not until this trial is over that the engine goes into the paint-shop, to exchange its rough lead-coloured livery for the beautiful coat of paint with which you are so familiar.

Later on there come some further and more important tests. Possibly you have, at some time or another, seen an engine with the front all boxed in, as in the case of the big Great Western engine, "Caldicot Castle," at the head of this chapter. This shows that the locomotive is in course of being "indicated." Indicating consists in obtaining curious boot-shaped diagrams on paper, which to those who understand them show exactly what is going on in the cylinders of the engine. The diagrams are drawn by the actual pressure of the steam in the cylinder, in a way that is a little too complicated to explain to you simply.

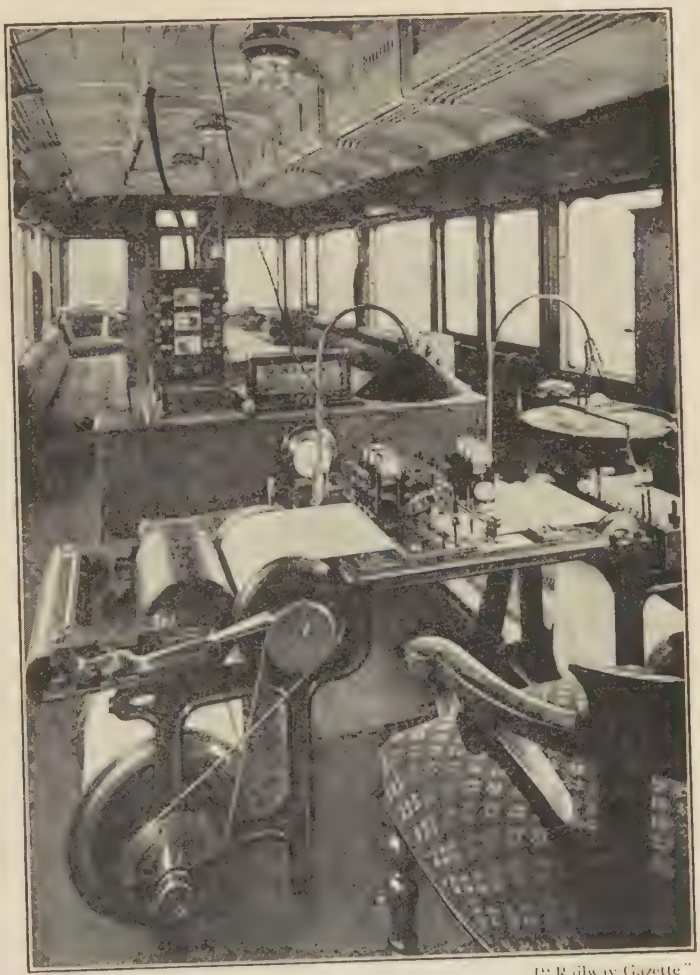
ON A "TRIAL TRIP"

The man who has charge of the indicating apparatus must be protected from the wind and the weather, as he rides on the front of the engine, and so these fine

shelters are now erected to make him as comfortable as possible. The idea of indicating the engine is to see whether it is really working as efficiently as it has been designed to do.

Other very important tests require the use of what is called a dynamometer car; you see some of the recording apparatus inside the Great Western car in the picture below. The chief object of this remarkable coach is to record exactly the "pull" exerted by the engine as it starts and draws along its train. So the hook of the car, to which the coupling of the engine is attached, is connected to a most complicated mechanism under the dynamometer car, which, by moving a pen, has the effect of drawing an unbroken line on a long roll of paper all the way through the journey.

The paper itself is slowly unwound by clockwork, and many kinds of other ingenious devices are used to mark on the paper all the mile-posts and stations passed, so that the exact work done by the engine at each point may be known,



[By courtesy] ["Railway Gazette"

DYNAMOMETER CAR, GREAT WESTERN RAILWAY

and various other records that are required. In the latest types of dynamometer car up to a dozen pens in all are used to make their different marks upon the long roll, each teaching its own lesson about the " performance " of the engine. The lessons thus learned are put into practice in later designs, so that the locomotives of to-day are always becoming more powerful and more efficient.

By courtesy] [L.N.E.R.

TRAIN-FERRY STEAMER, HARWICH TO ZEEBRUGGE SERVICE

TRAINS THAT GO TO SEA

IN various parts of the world there are wide waterways that interrupt the course of the railways, and in a number of such cases the water has been bridged by taking the trains themselves to sea. That is to say, the trains are run on to great big ferry steamers, which are arranged with lines of rails from bow to stern on which the wagons and coaches stand ; and when the water has been crossed, the vehicles are run off on to the railways on the other side.

Needless to say, the connection between the ferry-steamer and the railway lines on land has to be designed very carefully, as the steamer rises and falls in her " berth " with the tide. The trains are therefore run on to the steamer by means of a hinged bridge, which makes allowance for the height of the tide.

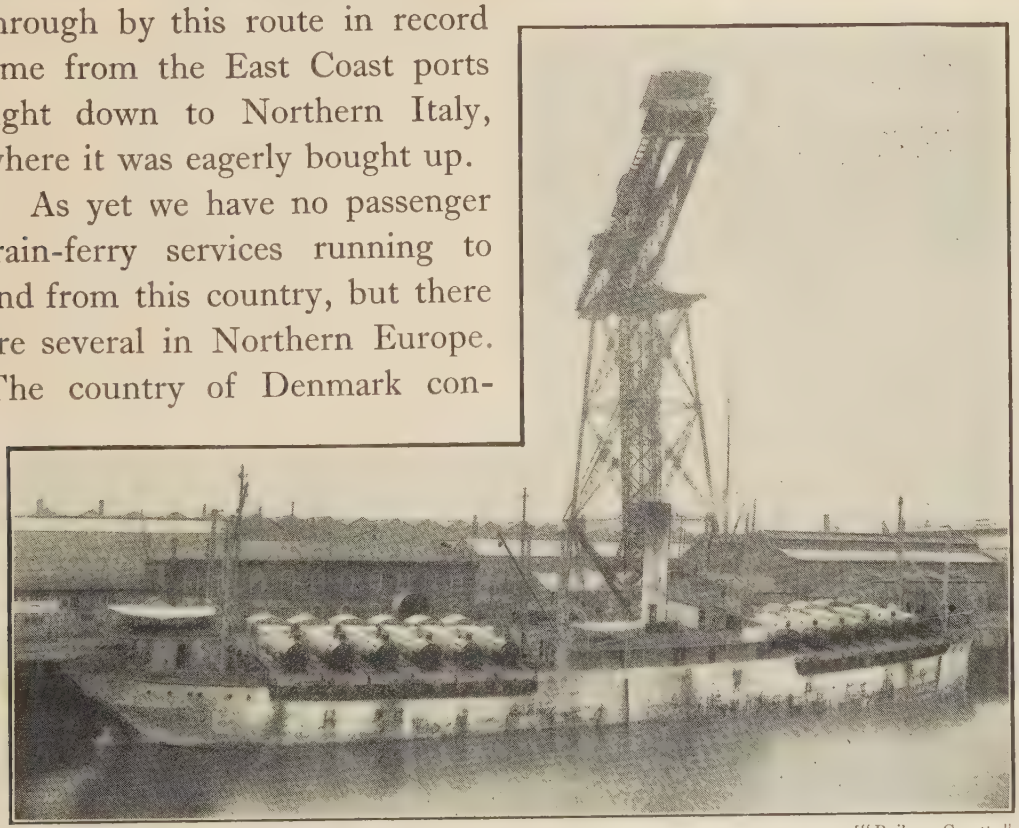
G.W.R. Cornish Riviera Limited Express at Full Speed.—
Engine "Pendennis Castle."

TRAINS THAT GO TO SEA

During the war tons and tons of munitions for our armies in France were loaded into wagons and run by train to Richborough, on the Kent Coast, taken over on the same wagons to Dunkirk, and run there straight on to the French railways. Had it not been for the ferry all the munitions would have needed to be transferred from train to steamer on one side, and from steamer back to train on the other—a slow and expensive business.

The first regular train ferry in the country is now being worked by the London and North Eastern Railway from Harwich, in Essex, to the famous port of Zeebrugge, in Belgium, and a stream of merchandise is being carried in both directions in through wagons. Recently, for example, a large consignment of fish was worked through by this route in record time from the East Coast ports right down to Northern Italy, where it was eagerly bought up.

As yet we have no passenger train-ferry services running to and from this country, but there are several in Northern Europe. The country of Denmark con-



By courtesy] NEW ENGINES FOR INDIA ON BOARD SHIP ["Railway Gazette"

sists mostly of islands, and its capital city—Copenhagen—can only be reached by railway by means of train-ferries. All the important trains between Copenhagen and other parts of Denmark, Germany and Sweden, are worked in this way. Most of these journeys involve at least two water crossings, and sometimes three.

Locomotives do not usually travel with their trains on these ferries ; but on the Oakland ferry of the Southern Pacific Railroad of America, out of San Francisco—the largest in the world—complete engines and trains, all coupled together, are carried over the water. The capacity of this ferry on one trip is 2 locomotives, 18 passenger coaches and 32 freight cars, all much heavier than those we use over here.

The other picture in this chapter shows a rather different kind of sea-trip. It represents a whole series of twelve engines, built at the great Beardmore locomotive works at Dalmuir on the Clyde, loaded on to a steamer ready to make their long voyage to India.

Seeing Scottish Scenery in the "Maid of Morven"

PULLMAN OBSERVATION CAR "MAID OF MORVEN"

SEEING THE SCENERY

ON the railways of America it is a favourite practice, on the chief expresses, to make the last coach at the back of the train an "observation car." It is provided with windows all round the rear end, so that the fortunate people inside have a practically uninterrupted view of the scenery along the line, mile after mile, as the train hurries along and leaves it behind. At the back of the car is an open platform, and there is a good deal of competition, in fine and warm weather, for the seats in this jolly position.

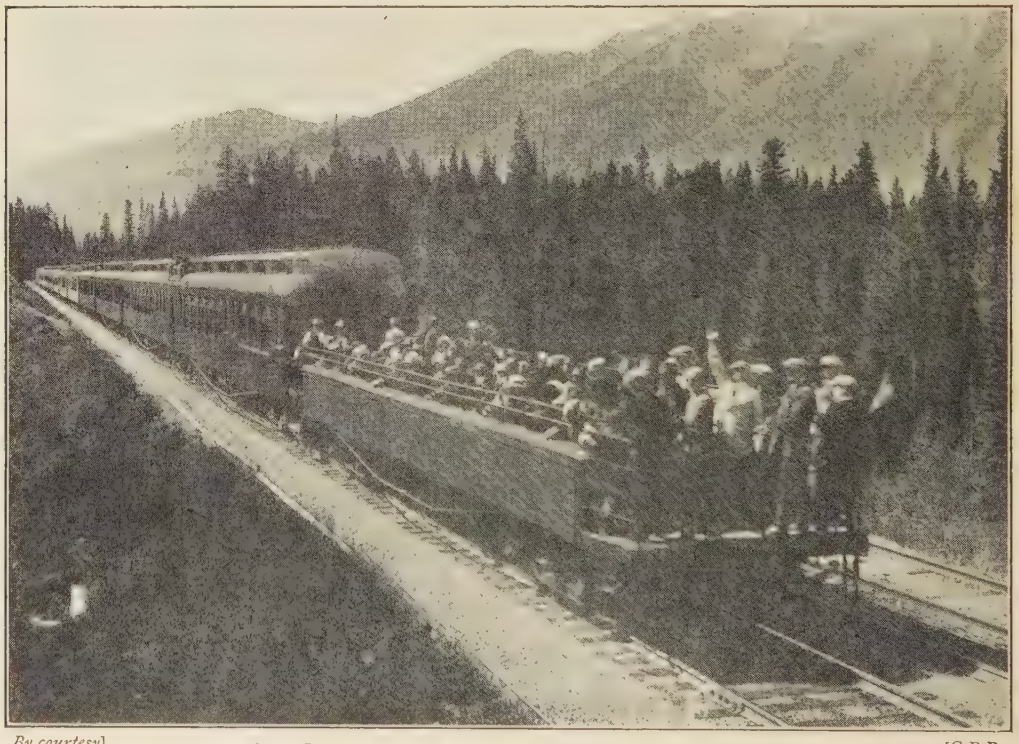
On the long Canadian Pacific journey across the Rocky Mountains, for hour after hour the train passes slowly through the most magnificent scenery. So that the passengers may enjoy this to the full, the large open car has been built that you see in the last picture. This will accommodate quite a large proportion of the passengers on the train, instead of just the favoured few who can get into

By courtesy] [C.P.R.

A CANADIAN OBSERVATION CAR

the observation car proper ; and in the middle of the summer it is clear that there is no lack of people anxious to travel in this open-air fashion.

Not much has been done in this country by way of building observation cars, although there are a few in use. Of these the finest is undoubtedly the beautiful Pullman car, " Maid of Morven," which is run by the London, Midland and Scottish Railway during the summer from Glasgow to Oban, in the West Highlands of Scotland. The passengers sit in the big bow window at the back, and enjoy from Callander to Oban an unbroken panorama of one of the loveliest successions of mountain and valley, moorland, loch and sea that could be found anywhere in our country. It is a trip that, once made, you are never likely to forget.



By courtesy] AN OPEN-AIR CANADIAN OBSERVATION CAR [C.P.R.

THE END

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